A Preliminary Summary of

Progress and Plans

SOILS, WATER AND FERTILIZER RESEARCH

of the United States Department of Agriculture
and
in cooperation with
State Agricultural Experiment Stations

Prepared for the Department's
SOILS, WATER AND FERTILIZER RESEARCH ADVISORY COMMITTEE

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This progress report is primarily a tool for use by advisory committee members in developing recommendations for present and future research programs and by USDA administrators for developing, coordinating, and evaluating research plans. Included in it are summaries of research done during the past year. Some are tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to advisory committee members, research administrators, and others having special interest in the development of public agricultural research programs.

The report also lists publications of research results issued during the year. Current agricultural research findings are also reported in the monthly USDA publications, "Agricultural Research" and "Agricultural Marketing."

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.

FUNCTIONS OF ADVISORY COMMITTEES

The Soils, Water and Fertilizer Committee is one of twenty-four commodity and functional committees of the U. S. Department of Agriculture established pursuant to Title III of the Research and Marketing Act of 1946. Functions of the members of these committees include:

1. Acquainting themselves with the problems of producers, processors, distributors, and consumers, and presenting them for committee consideration.

2. Reviewing the current research and marketing service problems of the Department and recommending adjustments, including terminations, in the current program in order that available funds, personnel and facilities will be used on problems of greatest importance.

3. Recommending new work or expansion of current work and indicating relative priority of such recommendations, when the current program is insufficient to develop solutions for important problems.

4. Developing a better understanding of the nature and value of the agricultural research program, explaining it to interested groups and organizations and encouraging the wider and more rapid application of the findings of research.

The committees perform an important function in advising with respect to the development of the Department's research and marketing service programs. However, committee members recognize that the development of budgets and the implementation and administration of research and marketing programs are responsibilities of the Department.

A progress report similar to this one is prepared for each committee. The areas of the other twenty-three committees are:

Citrus and Subtropical Fruit
Cotton and Cottonseed
Dairy
Deciduous Fruit and Tree Nut
Economics
Farm Equipment and Structures
Food and Nutrition
Food Distribution
Forage, Feed and Seed
Forestry
Grain
Home Economics
Livestock
Oilseeds and Peanut
Potato
Poultry
Refrigerated and Frozen Products
Rice
Sheep and Wool
Sugar
Tobacco
Transportation
Vegetable

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CODES TO DESIGNATE UNITS CONDUCTING RESEARCH

AGRICULTURAL RESEARCH SERVICE (ARS)

Farm Research Divisions

AE.....Agricultural Engineering
ADP.....Animal Disease and Parasite
AH.....Animal Husbandry
CR.....Crops
ENT.....Entomology
FE.....Farm Economics
SWC.....Soil and Water Conservation

Utilization Research and Development Divisions

EU.....Eastern
NU.....Northern
SU.....Southern
WU.....Western

Home Economics Research Divisions

CH.....Clothing and Housing
HHE.....Household Economics
HN.....Human Nutrition

AGRICULTURAL MARKETING SERVICE (AMS)

Economics and Statistics Divisions

AEC.....Agricultural Economics
AES.....Agricultural Estimates

Marketing Research Divisions

MD.....Market Development
ME.....Marketing Economics
MQ.....Market Quality
TF.....Transportation and Facilities

FCS.....FARMER COOPERATIVE SERVICE

FAS.....FOREIGN AGRICULTURAL SERVICE

FOREST SERVICE (FS)

Forest Research Divisions

FDR.....Forest Disease
FER.....Forest Economics
FFR.....Forest Fire
FIR.....Forest Insect
FMR.....Forest Management
FPR.....Forest Products Utilization
RMR.....Range Management & Wildlife Habitat
WMR.....Watershed Management

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I. WATERSHED ENGINEERING

1. SEDIMENTATION SWC

Problem: Isolation and evaluation of the erosion and sedimentation processes to develop new and improved criteria and procedural methods for assessing the significance of sediment problems and sources and for reducing sedimentation damages.

Program: A continuing long-term field and laboratory program directed toward obtaining a full understanding of the factors and variables that create and accelerate the processes of erosion, entrainment, and deposition of sediment. Involved is the collection and analysis of specific measurable field data from various watershed and streams throughout the country and the study of various factors and variables under controlled laboratory conditions. In the projected program the attempt is made to envision the areas of greatest and most urgent need and to develop procedures and criteria to answer these needs. Work is cooperative with State Agricultural Experiment Stations, Soil Conservation Service, and local state, and Federal agencies at 7 locations and involves about 14 Federal professional man-years annually.

Progress: Theoretical analyses and studies in connection with the use of radioactive tracers in sediment investigations were advanced at the Sedimentation Laboratory, Oxford, Mississippi. Pigeon Roost Creek sands were tagged with scandium in the laboratories of the Fertilizer Branch at Beltsville and plans advanced for testing in laboratory flumes and at controlled field locations to determine and perfect detection techniques, scaling requirements, and the potential of scandium tagged sand as a tracer in studying the movement of sediment in watersheds and stream channels.

Data acquired during the past year from the 12 key gaging locations in the Pigeon Roost Creek watershed, Osford, Mississippi, indicate a firm relationship between sediment concentration and instantaneous discharge for a particular watershed but extreme variability in annual sediment yield among the various subwatersheds. For example, one sub-basin had a total sediment yield of 0.53 ton per acre for the past year, whereas the same basin yielded 2.04 tons per acre in the previous year, even though the total rainfall and runoff were little different for the two years. The sediment yield for the 12 gaged areas varied from 0.48 to 5.15 tons per acre (1959). The wide range in these figures illustrates that sediment yields are highly variable from even adjacent watersheds and emphasizes the necessity of understanding the role of various factors that might be related such as: rainfall-energy, storm patterns and intensities, land use, and physiography.

Establishment of sediment delivery ratios to indicate the relationship between erosion in the watershed and the amount of sediment delivered from the watershed is one of the primary purposes of sedimentation investigations in Pigeon Roost Creek watershed. Studies are not yet

conclusive but quite preliminary figures indicate sediment delivery ratios ranging from 20 to 60 depending upon watershed size and other characteristics.

Determination of the unmeasured sediment load (that portion moving in the zone between the stream bed and the entrance nozzle of a standard suspended sediment sampler) by use of available theoretical and empirical relationships, indicated that the unmeasured portion averaged 23 percent of the total sediment load at stations in the Pigeon Roost Creek watershed. The magnitude of this unmeasured segment, and the fact that it represents the coarser sediments which are significant in entrainment and deposition evaluations, demonstrates the need to establish methods for accurately determining the unmeasured load for various channel and sediment types and for improving the understanding of relationships between the unmeasured and measured movement.

Considerable work has been accomplished at the Sedimentation Laboratory toward assembling and analyzing available sediment and streamflow data, for drainage areas under 100 square miles, to establish sediment-rating curves and sediment yields for various physiographic and geographic regions. Preliminary findings indicate that similarities exist in the rating curves but that considerable selectivity of data is required to eliminate effects of upstream storage and diversion and to obtain adequate representation of long-term conditions.

The effect of land use and conservation practices on soil loss is an important segment of the overall erosion and sedimentation process. At Holly Springs, Mississippi, initial results of soil loss studies carried out during two high rainfall events indicate no difference in soil loss between watersheds in corn under conservation and those under non-conservation practices and that the loss from poor pasture areas was only one-twentieth of that from the areas in corn. Considerable more research on this is necessary before firm conclusions can be drawn.

Resurvey of 12 ponds and reservoirs at Newell, South Dakota, and the analysis of their deposits has illustrated that the presence of bentonitic type materials in significant quantities causes bulking of reservoir sediment, thereby affecting deposition patterns and the space occupied in the reservoir.

Detailed mapping of vegetative cover in the Walnut Gulch watershed near Tombstone, Arizona, revealed a highly significant relationship with soils and parent geologic materials. A sediment source map for this area, based on soil surveys and on-the-ground determinations, indicates that the majority of the sediment is produced by a relatively small portion of the total area where vegetation and soils are conducive to erosion.

A sediment sampling program has been reinstituted on 5 experimental watersheds at Riesel, Texas, in further study of the sediment and erosion characteristics of Blackland soils. Analyses will include comparisons with data obtained from the same watersheds in the 1938-43 period, and studies of sediment production as affected by variations in land use and conservation practices and size of the watersheds.

A new radioisotope sediment densitometer was used in studying the density of sediment in a small reservoir in the vicinity of Oxford, Mississippi. Performance of the instrument was highly satisfactory and revealed variations in density from 20 to 80 pounds per cubic foot (dry weight) increasing with depth of the deposit and decreasing with distance upstream from the dam. It was concluded from these studies that the higher densities are the result of sorting and deposition of similar sized particles. Extensive studies of a similar nature are underway on Sabetha Lake in southeastern Kansas.

The accuracy of the sediment yield determinations obtained from reservoir resurvey data is related to the adequacy of the sediment range system and resurvey methods. At Lincoln, Nebraska, study of methods for computing reservoir capacities and sediment volumes, including the most desirable range layout, were investigated. Results indicate that there is an optimum number of ranges for a reservoir, that parallel ranges are preferable, and that the contour method of capacity determination is most acceptable.

Plans: Research will be continued to ferret out fundamental principles involved in erosion and sedimentation processes to aid in understanding and solving sediment problems. Emphasis in the immediate future will be on studies of sediment detachment, movement and deposition, using radioactive tracers to develop new information on sediment sources and delivery ratios. Distribution and density of reservoir sediment will also receive particular attention utilizing radioisotope methods for determining deposit densities. Staffing of the Sedimentation Laboratory at Oxford, Mississippi, is nearing completion and it is anticipated that increasingly rapid progress will be made in sedimentation research.

Publications: A New Laboratory for Sedimentation Research. Russell Woodburn. U. Ky. Kentucky Engineer 22(2): 30, 31, 34, 36, 38. 1960.

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2. STREAM CHANNEL STABILIZATION SWC

Problem: Watershed development programs often alter the natural regime of the stream system and sometimes an already deteriorating channel system is inherent in a planned project. To facilitate the protection and development of agricultural watersheds, and reduce the maintenance cost associated therewith, new and improved concepts and criteria for channel stabilization and control are necessary.

Program: A continuing program of laboratory and field research directed toward advancement of knowledge and the development of new and improved methodology. Involved are: (1) segregation and evaluation of measurable variables affecting channel regimen including resistance factors, shear, velocity, and sediment transport; (2) isolation and evaluation of properties of stream bed and bank materials that affect the resistance of the bed and banks to scour action; (3) development of criteria for predicting the effect of a watershed program on channel regimen, and (4) development of criteria and aids that can be used in selecting and placing channel stabilization measures. The present program includes collection and analysis of pertinent field data from various geographic and stream type locations and research contracts with institutions for the study of basic regimen factors and methods of measurement. The program is cooperative with various state and Federal agencies at 5 locations in 5 states and involves about 6 professional Federal man-years annually.

Progress: Some initial criteria on shear stress and scour action in stream bends have been established from hydraulic and hydrologic data collected during flood events on Buffalo Creek, New York, aerial photographs, analytical studies of channel geometry, and limited special contracted laboratory model experiments at the Massachusetts Institute of Technology. Shear stress patterns indicate maximum shear points at the upstream inner boundary and downstream outer boundary with the critical point near the toe of the bank slope. Mathematical expressions have been derived that relate requisite riprap size to shear stress and channel geometry. Field tests on a reach on a river bend utilizing cellular blocks with inserted materials of varying size and specific gravity, have essentially confirmed the shear stress findings in the hydraulic and analytical studies and in the laboratory experiments. Expansion of these investigations to other type channel and geographic regions is contemplated along with expansion of the laboratory studies to reflect a wider variety of natural conditions. In the Buffalo Creek field studies it has been found that vegetation, once established, can be an effective scour deterrent in regions of moderate shear stress.

Studies of Pigeon Roost Creek data at the Sedimentation Laboratory, Oxford, Mississippi, are confirming the importance of sediment transport and significance of hydraulic factors in channel regimen. Recent studies of sediment transport and channel cross-section data show that a dredged channel reach in a sand carrying stream, without other control measures, will rapidly build back to the original gradient of equilibrium. Also indicated is a reduction in sand carrying capacity below the confluence

of two tributaries. The hydraulic factors associated with this transport reduction are being studied.

Also evident from the Pigeon Roost Creek data is the existence of an intricate relationship between sediment transport, channel roughness, stream bed configuration, and hydraulics of channel flow. Associated laboratory flume studies, being carried out under contract at California Institute of Technology, are showing that channel wave lengths and amplitudes are directly related to the bed configuration, and therefore to observed channel hydraulic behaviour. Both the field data analyses and laboratory experiments confirm the concept that more than one flow quantity can occur at the same stage in a sand-bed channel.

Under a research contract, work is nearing completion at Colorado State University on development of a fully transistorized ultra-sonic device that will permit simultaneous measurement of water surface and stream bed profiles. Initial laboratory tests of the instrument indicate excellent performance. By special adaptation to a standard 100 pound current meter weight, the instrument can be used in natural channels. This device will permit acquisition of data in laboratory flumes and in natural channels that have been unattainable heretofore and that are directly pertinent to channel hydraulic and sediment transport phenomena.

At Madison, Wisconsin studies have been initiated to determine any changes in stream channel gradients resulting from deposition or scour associated with gully control and small flood detention structures constructed in the 1930's. The probable gradient to be established by various type sediments in relation to drainage basin characteristics, and hydraulic and hydrologic factors, is an important item in structure planning and design.

Recently the use of various channel liners has been advocated to protect newly emergent vegetation in farm waterways. At Stillwater, Oklahoma, initial studies of jute mesh, hay mulch, and paper strand mesh linings have been completed. Results for the conditions studied indicate that fine mesh jute will resist erosion of some soils at velocities up to 3.6 ft/sec., and that open weave mesh will only protect against 1.3 ft/sec. velocities. Hay mulch and paper strand mesh were not too effective as channel protectors.

Studies of sediment transport and channel stability were initiated on a reach of Laboratory Creek, a small natural channel adjacent to the Sedimentation Laboratory at Oxford, Mississippi. Studies in this channel will permit an evaluation of findings at the various Pigeon Roost Creek measurement stations and will also provide a ready means of comparing flume results with natural channel characteristics. The large laboratory sediment transport flume is being instrumented and tested prior to loading with Pigeon Roost Creek sands.

The study of changes in bed elevation of Pigeon Roost Creek channel, using comparative cross-section data, were continued. Results indicate a general slight scour in the upstream reaches and a slight filling in the lower reaches. This would support the premise that sand load

produced in the upper basin areas is not wholly transported out of the basin.

Channel degradation studies of East Goose and Little Rock Creeks in Mississippi show that sand filled channels degrade following retention of sediment upstream and that a relationship exists between the sand retention and the downstream sand scour.

Plans: The current requests for information on stream channel phenomena and criteria for stable channel design make it imperative that this research program be advanced as rapidly as possible. The new facilities at the Sedimentation Laboratory, Oxford, Mississippi, will materially aid in the investigations. Continued efforts will be made to advance the under-standing of basic phenomena involved in channel regimen and to establish needed criteria on methods of channel rectification and control. Special emphasis in the immediate future will be placed on the study of stability in cohesive materials and the relationship between channel geometry, shear stress, and protective measure requirements. Coordination between laboratory experiments and general field investigations will be continued.

Publications: A New Laboratory for Sedimentation Research. Russell Woodburn. U. Ky. Kentucky Engineer 22(2): 30, 31, 34, 36, 38. 1960.

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3. FACTORS AFFECTING WATER YIELDS FROM AGRICULTURAL WATERSHEDS SWC

Problem: Rapidly increasing demands for dependable water supplies are posing many problems. Solutions require knowledge of how the quantity and quality of water from agricultural watersheds are affected by watershed protection measures and the most desirable combination of soil and water conservation practices for watersheds where optimum production of water with a minimum of sediment burden is the primary objective.

Program: A continuing program of research to identify and evaluate the effects of land use and soil and water conservation practices upon the water yield of upstream areas and to devise guidelines for selecting the combination of soil and water conservation practices and watershed treatment measures most effective in providing maximum yield of high quality water. The studies are cooperative with State Agricultural Experiment Stations and other State and Federal agencies at 20 locations and involve about 12 Federal professional man-years annually.

Progress: At Ft. Lauderdale, Florida depth to groundwater surface bore consistent relationships to outflow from the Taylor Creek watershed. Slopes of these relationships substantiate the limits and characterization of direct runoff, interflow and base flow previously derived from analyses of channel flow hydrographs in that area. Annual water yield is predominantly base flow with interflow next and direct runoff the least contribution. Since annual water yield per unit area on this watershed decreases downstream, further investigation of factors, such as the extent of areas having high water tables and riparian losses, are in order. Although water is plentiful in Florida, precise management is critical to continued progress in agriculture, industry and urban development.

At Coshocton, Ohio a surface-water survey was made on a 300-acre watershed during a rainless period to determine the sources and regimen of base flow. An independent geologic survey, from inspection of the surface only, was prepared as an overlay of the surface-water survey map. From the overlay it became apparent that flows originated near geologic out-crops and disappeared when the channel crossed coarse rock debris and alluvials, to reappear as the channel bed again approached bed rock. Heads of major channels consistently appeared in close proximity to outcrops of the same geologic strata, Middle Kittanning coal. Techniques such as these, if fully developed should prove practical for watershed planning parties in estimating the influence of geology on water yields of agricultural watersheds. Results of these surveys refute the popular assumption that water yield is a function of size drainage area or of elevation. They indicate that geology must be considered in relation to the position of the stream. A geologist and drill rig have been assigned to further investigate the geology of this watershed and subsequently larger areas in the vicinity.

At Danville, Vermont measurements of base flow from 31 tributaries on December 4, 1959 accounted for 97 percent of the base flow on the main stream at the gaging station. These measurements are to be used for correlating flows with geology-soil-land use complexes in the various tributaries. The close approximation of total flow during the dormant season indicates that a rather complete accounting of base flows should be feasible in this area. Repetition of the measurements is planned during the growing season in 1960 to determine the effects of plants upon riparian losses. The increasing interest of urban developments of the Northeast in the management of watersheds for water supply must be coordinated with agricultural interests and the needs for protection of watersheds against the ravages of erosion and flooding. Subsurface storage and base flow are beneficial to all three interests and should be an integral part of watershed protection program planning and evaluation.

Three runoff measuring stations in tandem on Walnut Gulch at Tombstone, Arizona in 1959 permitted for the first time a really adequate measurement and evaluation of runoff transmission losses in an ephemeral sand-bed channel typical of the southwestern part of the country. Losses during larger flows reached a high of 17.7 acre-feet per mile. The two greatest events closely approximated 3.5 acre-feet per mile per hour of flow, in spite of differences in antecedent flow. Although the volume of runoff was consistently reduced by transmission losses, reductions in peak rate

of flow were less consistent. In a dry stream bed, transmission losses reduced both volume and peak rate of runoff by more than 90 percent in a reach of 5 miles. But in another instance following antecedent flow, reductions which exceeded 60 percent of the volume resulted in less than a 10 percent reduction in the peak flow. Disposition of these losses depends upon the geology immediately beneath the streambed and upon the vegetation present.

Dense growth of mesquite and other shrubs define the approximate boundaries of perched aquifers beneath the Walnut Gulch channel. Records of groundwater levels in one of these perched aquifers over a 4-year period indicated an average drop of 0.01 foot per day during the dormant season and 0.04 foot per day drop when the mesquite and other shrubs were growing vigorously. Runoff records indicate that these perched aquifers must be filled successively downstream before base flow can occur. Further investigation is required to characterize the processes of runoff absorption in alluvial channels and to evaluate the effects on downstream water yield in the arid Southwest.

Plans: Studies of water yield at downstream points along the Washita River (Oklahoma and Texas) in relation to watershed protection measures in upstream tributaries will be initiated. The water balance study begun last year in Reynolds Creek Watershed, in southwestern Idaho, will be continued and investigations pursued at other existing field locations. Plans are underway to obtain geologic information pertinent to the accretion and movement of groundwater in selected watersheds over the nation where hydrologic records are currently maintained. These geologic studies will provide information on the conformation and lateral extent of aquifers underlying watersheds and the cross section of water bearing alluviums at stream gaging stations to better define total water yields.

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4. HYDROLOGIC PERFORMANCE OF AGRICULTURAL WATERSHEDS SWC

Problem: The control, conservation, and use of available water resources requires better data and understanding of precipitation-runoff-groundwater relationships as affected by soils, land use, conservation treatments and climatic, geologic and other features of agricultural watersheds, as well as new and improved methodology.

Program: A continuing long-term program of hydrologic research to establish the influence of factors such as climate, physiography, geology, soils and land use and treatment practices upon surface runoff, subsurface flows, and deep seepage on upstream agricultural watersheds. The work is cooperative with State Agricultural Experiment Stations and other State and Federal agencies at 20 locations in 17 states and involves 23 professional Federal man-years annually.

Progress: At Boise, Idaho, progress was made on establishing the Northwest Watershed Research Center. The 88-square mile Reynolds Creek Watershed, about 50 miles southwest of Boise, has been selected for detailed study. This watershed is primarily rangelands, representative of large areas of the Snake River Plains and other parts of Idaho, Washington, Oregon, and Nevada. Greatest research emphasis will be placed on the understanding of the hydrologic cycle as it pertains to water yield. Installation of the necessary instrumentation began in the construction season of 1960.

At Riesel, Texas, a method has been developed for estimating daily runoff for Blacklands areas using daily rainfall, soil moisture, and land use parameters. Daily soil moisture, used as an indicator of the available storage for precipitation, is estimated through its relationship to pan evaporation, land use, and daily rainfall and runoff. The method has been checked for areas with mixed land use and measured rainfall and runoff at the Blacklands Experimental Watersheds. Close agreement between computed and observed runoff has been obtained. When fully developed the method will make it possible to predict runoff from areas with various combinations of land use. Reasonable estimates of the effects of proposed land use changes on surface runoff can then be made for a design storm or a selected evaluation period.

From headquarters at Tucson, Arizona completion of an additional key runoff measurement flume on Walnut Gulch Watershed now makes possible unique observations on the channel hydraulics of storm runoff. Inflow and outflow to a 5 mile reach of ephemeral sand-bed channel, typical of upstream rangeland watersheds of the southwest, can now essentially be measured. For the storm of August 3, 1959, when the channel was wetted by antecedent flow, the volume of flow through the reach was reduced by more than 60 percent because of accretion to the alluviums. The peak rate of discharge, however, was practically the same at the entrance and exit ends of the reach, being 1375 cfs and 1300 cfs respectively. Mean velocity of the flood wave crest through the reach was 9 feet per second. For another event, when the stream bed was dry, accretions to the alluviums reduced both the volume and rates of flow.

The rainstorm on snow-covered frozen ground which occurred at Coshocton, Ohio on January 20-21 was a hydrologic event of major importance. Though the soil has frozen every year and the watershed lands have been covered with snow from time to time, this was the first time such conditions happened concurrently with a significant rainfall. Peak rates of runoff from this event on the Coshocton watersheds ranged from 0.24 to 0.50 inch per hour--not exceptionally high for watersheds of 29 to 4,580 acres in size. The runoff volume for any one of the three peaks in the period ranged from 0.90 to 1.24 inches and the total volume for the entire flood period was about 3 inches. High volumes of runoff for a one-day period occurring over a wide area was the cause of major flooding and flood damage along streams draining the large watersheds in Ohio and neighboring states.

In the Ohio region the maximum flood period for watersheds of 5,000 acres and less is the summer season. The records at Coshocton show that the peak and greatest volume of flood flows for the watersheds of this size range occurred in June, 1957. Peak rates ranged from 3.72 to 0.61 inches per hour and volumes for single peaks from 1.26 to 1.83 inches. For the single events, the summer peaks were over twice as great as for the 1959 winter peaks and the volumes were at least 50 percent greater. The summer storms are usually local in nature, and cause major flooding and substantial damage to growing crops and pastures in upstream areas--but they do not extend over whole states or regions. On the other hand, the region-wide winter storms like that of January 20-21, 1959 cause minor floods in upstream areas--but the flows from the many hundreds of upstream areas combine to cause major floods in the downstream areas.

All the field stations cooperated in assembling and distributing a third volume of information from the backlog of basic hydrologic data. The volume is titled "Selected Runoff Events for Small Agricultural Watersheds in the United States". From the file of data, two to four storm runoff events were selected for each of about 60 representative experimental watersheds throughout the country. The information presented for each storm event includes: tabulations of antecedent daily rainfall and runoff for 30 days before the event, rainfall intensities and accumulated amounts for the event, runoff rates and accumulated amounts for the event, watershed conditions at the time of the event, hydrographs and rainfall histograms, and a watershed map. Publication of this document completes the distribution of the "backlog of data" and hereafter it will be the aim to keep publication current.

From headquarters in Madison, Wisconsin, runoff investigations are carried out on watersheds near Fennimore. A severe winter, with temperatures averaging 7 degrees below zero, froze the soil of the watersheds there to depths of over four feet. Heavy snowfalls in February and March left depths of 18 to 24 inches on parts of the area. Melting began on March 19. Soil moisture samples had been taken in November 1958 and in April after the snow melt season. The samples showed no increase in soil moisture though there was capacity in the profile for additional moisture storage. The aspect of the watersheds had a significant effect on snow deposition and melt. The south facing watershed not only caught more snow but

melting was also faster.

At Danville, Vermont, special attention was given to planning investigations for developing an understanding of, and for evaluating, the factors influencing the deposition and disposition of snow. Some instrumentation for these investigations has been installed on the Sleepers River Experimental Watershed where snow course and other data are being collected and processed, but additional instrumentation is needed.

From the headquarters at Riesel, Texas, a study was made of the effect of various tillage treatments on the runoff producing characteristics of the nine small continuous wheat watersheds at Cherokee, Oklahoma. The watersheds were operated for a nine-year period with different tillage treatments and for another 5-year period with the same tillage treatment. The analysis showed statistically significant differences in annual runoff between basin listing, with an average annual runoff of 3.2 inches for the nine-year period; stubble mulching with 4.20 inches; and wheatland discing with 4.91 inches. These results are dominated by the years with above average rainfall. The analysis also showed that the treatment producing the most runoff also produced the largest crop yield.

At Hastings, Nebraska the second year's results from a recommended subsurface tillage system, carried out on small single crop watersheds, showed some indication that this system may be effective in runoff control during the wheat and sorghum periods. In 1959, a wet year with 28.9 inches precipitation, there was 4.3 inches of runoff from subtilled wheat and 4.8 inches from subtilled sorghum in rows. A comparison with 15 years of prior records on these watersheds showed this was less runoff than would have been expected under a straight row system. Two fallow subtilled areas produced 9.3 and 5.6 inches of runoff, amounts almost equal to the largest annual flows recorded from the watersheds in 20 years of record. Some need for improvement in the fallow system is indicated.

At Moorefield, West Virginia where four small watersheds were instrumented in 1958 to evaluate the factors affecting runoff from pasture on shallow shale soil, storm intensities and amounts have not been great enough to cause other than very low flows from the watersheds. The pattern of runoff behavior between watersheds--even for the low flows--cannot yet be defined. The calibration period must be continued until the basic hydrologic performance of each of the watersheds can be characterized. After the characterization of the watersheds is completed, the shale subsoil of two of them will be shattered with a Killifer chisel.

At Ft. Lauderdale, Florida studies of controlled water levels indicated that evaporation from the groundwater surface during the production of truck crops increased from zero, when the water level was at depths of 32 inches or more, to greater than open pan evaporation when the water level was near the surface. Under St. Augustine grass, the water level had no effect on evapotranspiration losses. Efficient designs of canals, pumps and land use programs in Florida are dependent upon reliable estimates of the accretion, movement and dissipation of groundwater.

At Tucson, Arizona the raingage network on Walnut Gulch Watershed indicated that 40 percent of all storm cells are larger than one square mile but smaller than two square miles. Further, 80 percent of all storm cells are smaller than four square miles in size. For the period of record the average density of these storm cells has been 2.58 per square mile per year. Of the convective storms 80 percent attained maximum intensities greater than 2 inches per hour, while 15 percent attained intensities greater than 4 inches per hour. Durations of these same storms showed that 80 percent were shorter than 5 hours, with the bulk of the rain falling in a much shorter time. A study of daily distribution of storm cells revealed that more than 3 times as many storms occurred between the hours of 8-10 a.m., and 5-11 p.m., than at any other time of day. Seventy-one percent of the winter storms and 61 percent of the summer storms fell in amounts smaller than 0.25 inch. It is extremely rare for a winter storm to exceed 1.5 inches while it is relatively common with the summer storms.

Plans: Research will be planned and initiated in the Washita River Watershed (Oklahoma and Texas) with primary emphasis on studying the relation between conservation and watershed protection measures in tributary watersheds and the water regime of the main river channel. Hydrologic data collection will be improved and supplemented at existing field locations. Continued and increased emphasis will be placed on analysis of data and coordination of results between locations. Geologic information will be obtained in sufficient detail on selected watersheds for more comprehensive hydrologic accounting including studies of groundwater accretion and movement, return flow to streams, and losses of streamflows as affected by geologic characteristics such as strike, dip, stratification and permeability of aquifer materials.

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5. ENGINEERING DESIGN OF CONSERVATION STRUCTURES SWC

Problem: Provide theory and basic data for the hydraulic design of structures and channels used in watershed protection programs for controlling and conserving soil and water.

Program: A continuing program of hydraulic research to provide generalized design criteria for structures, channels, and related appurtenances for water conservation, disposal, regulation or control on agricultural watersheds. Cooperation is maintained with State Agricultural Experiment Stations, Soil Conservation Service, and other local, State and Federal agencies. The effort involves about 6 Federal professional man-years per year.

Progress: At Stillwater, Oklahoma a technique was developed for model testing the performance of trash guards for use on the drop-inlet spillway for reservoirs and ponds. Tests showed that short strands of hemp rope treated with a sulfuric acid solution could be used in model studies to simulate the actions of trash normally encountered in a reservoir.

Models were also used in studying the hydraulic performance of an orifice plate on the top of a drop-inlet to reduce the flow. The minimum diameter of 17 inches for primary spillways of reservoirs, adopted for strength and ease of maintenance, often results in a rate of discharge too great for the downstream channel condition. In current practice an orifice plate is placed over the top of the drop-inlet to reduce the rate of discharge. The tests indicated that a vacuum forms beneath the plate during high flows and that the hydraulic head is then a summation of the vacuum head in the riser and the head equal to the depth of water above the plate. Under these conditions pipe flow governs throughout the structure and the orifice is merely another resistance to pipe flow. Tests showed that it would be necessary to vent the drop inlet to maintain orifice control.

At Minneapolis, Minnesota models were used to determine the hydraulics of flow through a drop-inlet spillway as affected by a hooded entrance to the barrel at the bottom of the drop-inlet. Tests showed that smaller drop-inlets can be used with the non-projecting hood than with the projecting hood. Also, entrance loss coefficients in small drop-inlets are less for the non-projecting hood-inlet than for the projecting hood-inlet.

Model studies at Minneapolis, Minnesota are providing information for the design of the two-way drop-inlet. In field practice, to prevent vortices, two opposite sides of the drop-inlet are extended upward a few feet above the other two sides and a horizontal slab is placed on top, thus leaving two sides open for the entry of flow. The horizontal slab overhangs the two open sides and serves as an anti-vortex plate. This design provides structural advantages, but poses some problems in hydraulics. The laboratory has tested 62 different arrangements of the two-way inlet since the tests were initiated in April. It has been found that the length of the flat anti-vortex plate influences the head-discharge relationship when the spillway is partly full: the longer the overhang, within certain limits, the lower the head for a given discharge. Similar results are being obtained by the Illinois State Water Survey Division at Urbana, Illinois, on circular flat anti-vortex plates. No explanation of this phenomena or means of predicting its magnitude has yet been found. It was thought that the effect of surface tension in the model might have been a factor, but the same results were obtained when aerosol was added to the water to reduce the surface tension. The test data are now being analyzed in an attempt to discover the laws governing the flow into drop-inlets having flat top anti-vortex devices.

A movie report of tile junction studies at Minneapolis was completed and released. This sound-color movie contains some field scenes, shows the laboratory experimental apparatus, and illustrates how the flow from the lateral joins the flow in the main. Joining flows are shown for various proportions of the flow from the lateral, for various sizes of lateral discharging the same flow, for various sizes of main with each lateral discharging the same flow, for several entry angles, and for laterals entering the main at the top and at the centerline. The movie shows that the energy loss at junctions for different angles of entry are so nearly the same that they are usually unimportant in agricultural drain tile

systems. This means that the lateral can join the main at the most convenient angle without significantly affecting the loss at the junction.

Model tests at Minneapolis were of much importance in developing the final design and plans for the runoff station at 16.8-square miles on Houghton Brook in Vermont. A sharp curve upstream of the first weir site selected caused extremely asymmetrical flow at the weir and undesirable overbank flow. Model tests indicated that moving the weir upstream of the curve and locating it at the end of a straight reach of stream resulted in satisfactory flow conditions and an acceptable rating curve.

The runoff measurement flume at site No. 2 on Walnut Gulch, Tombstone, Arizona, modeled and tested in the Outdoor Hydraulics Laboratory, Stillwater, Oklahoma, was completed in April 1959. Eleven flow events passed through the flume during July and August, the largest of which had a peak of 3,700 cfs. Performance of the flume, which has a discharge capacity of 18,500 cfs, was very satisfactory. Numerous sequence photographs and movies of two of the flows helped verify the model-prototype relationship for the structure.

Plans: Studies of the hydraulics of the tabletop anti-vortex baffle on the two-way drop-inlet will be continued at the St. Anthony Falls Laboratory. It has been found that air instead of water can be successfully used to speed up certain phases of this investigation. Various designs for debris guards on spillways will be developed, tested, and rated and studies of the hydraulic performance of vegetated spillways and waterways will be continued at the Outdoor Hydraulics Laboratory, Stillwater, Oklahoma.

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II. SOIL AND WATERSHED MANAGEMENT IN FORESTS AND RELATED RANGELANDS

1. HYDROLOGIC AND EROSIONAL PROCESSES ON FOREST AND RELATED WATERSHEDS WMR

Problem: Improved knowledge of the hydrology of soils and the functioning of plants and the relationships of soils, water, and plants in water use and soil stability are needed to establish principles of management for application to many forest and related watershed complexes.

Program: Continuing basic research on the processes of water movement in soils and plants, the nature and effects of precipitation, temperature, humidity, solar radiation and other climatic factors; the structure, texture and composition of soils in relation to erodibility and moisture storage, and on the problems of instrumentation and research techniques for measuring little known processes is part of the program at each regional forest and range experiment station. The research is cooperative with 9 Federal agencies, 16 State, 3 municipal, and 14 private organizations. About 30 professional Federal man-years are used in this work.

Progress: The disposition of precipitation after striking the earth's surface is also important. In the Sangre de Cristo Mountains in New Mexico there is considerable wind movement in the snowpack zone and snow intercepted by conifers rarely remains on the crowns. This wind movement often fosters what might be termed positive interception, that is, snow swept off open areas accumulates in the surrounding timber forming deep, slow-melting drifts. On the open and aspen-covered south slopes, soils are predominantly frozen, generally to a depth of only 4-5 inches but enough to prevent movement of snowmelt water into the soil profile. Melt water apparently moves downslope through the humus and upper one inch of soil.

Under some circumstances a rather high proportion of the precipitation is intercepted by trees or other vegetation. Net rainfall in a northern hardwood stand in New Hampshire was calculated from two summers' measurements of gross rainfall, rainfall reaching the ground through the trees, and rainfall flowing down tree stems. For storms 0.8 inch and larger, through-fall accounted for about 90 percent of gross rainfall, and stemflow for about 6 percent. Variation was found to be inversely related to size of storm up to 0.5 inch rainfall; for larger storms the coefficient of variation was about 15 percent. Stemflow from a 10-inch beech during a 1.0 inch storm amounted to 90 gallons of water, equivalent to a depth of 7.4 inches over an area one foot radius from the tree trunk. An average of two-thirds as much water flowed down the rough-barked sugar maple as ran down the beech. Streamflow on the curly-barked yellow birch averaged about one-half the amount measured on the beech. For a given species, stemflow was found to vary according to position of crown and the lean of the tree.

Also receiving study are some of the factors involved in overland flow.

Near Oxford, Mississippi, 12 small experimental watersheds, representing four cover types--old fields, depleted hardwoods, 20-year-old loblolly pine plantations, and mature upland hardwood pine--were studied for information on surface runoff and soil erosion. In 1958, surface runoff and peak flows were greatest from abandoned fields, intermediate from depleted upland hardwoods, and least from 20-year-old loblolly pine plantations. Surface runoff under each cover type increased directly with proportion of the watershed in loessial soil. Soil moisture, rainfall, and surface runoff records from one old-field watershed during a two-year period indicate that surface runoff is strongly correlated with storage opportunity in the surface 6-inch soil layer.

For plant growth and runoff control, infiltration of water into the soil is important. Ring infiltration measurements on four logged watersheds near Elkins, West Virginia, were made in the tractor tread area, the center of the skidroads, and in essentially undisturbed areas adjacent to the skidroads. Average time to infiltrate one inch of water on prewet soils was 5.5 minutes in the tread area, 2.8 minutes in the area between the treads, and 0.6 minute in the undisturbed. In New Hampshire, concrete soil frost was found on three times as many days in a white pine plantation as in red pine. When frost occurred in both plantations, it was found in two to three times as many places in white pine as red pine. Humus layer depths may explain the difference. In the red pine, humus was 2.7 inches in depth while in white pine only 1.6 inches. There was no significant difference in snow depth in the two plantations.

Even though precipitation may be absorbed by the soil, there may be a great variation in the water storage characteristics of soils under different conditions. In southeastern Ohio the moisture content of a shallow (36-inch) soil with a well-developed profile with a dense, impervious shale subsoil was measured on plots covered by oak, pine, grass, brush, and deforested. Late summer soil moisture deficits were greatest under oak, followed in descending order by pine, brush, grass and deforested. Total water used in a 6-month growing season ranged from 21 inches under deforested to 25 inches under pine. Additional water was used by pine during the dormant season and the 2-year average amount of precipitation required to recharge the soil was 6-1/2 inches greater under pine than under grass, grass being the minimum cover condition practical to maintain the necessary soil stability. These results indicate that there is a good opportunity in the Central States to regulate streamflow and reduce floods through the manipulation of forest cover. They exemplify the two opposing objectives that may be proposed in a watershed management program, one being the possibility of increasing streamflow by decreasing transpiration through a reduction in the vegetation cover, and the other possibility of decreasing floods by providing in the soil the maximum amount of storage space for precipitation through the maintenance of a heavy growth of vegetation.

Soil moisture depletion was studied in an Arizona clay soil under a stand of Utah juniper by taking measurements at 6-inch depth intervals in 30 inches of soil. Soil moisture use in 24 to 30 inches of soil was not

related to stand density. Soil moisture use over a year's time was related primarily to net precipitation and average soil depth. Soil moisture samples, taken on areas where Utah and alligator juniper had been destroyed by cabling and on natural areas, showed no difference in water use during the summer rainy season. A net accretion in soil moisture storage of about 0.75 inch resulted from about 6 inches of precipitation during the rainy period June 20 to September 1.

Perhaps the greatest loss of moisture from soil is through evapotranspiration of the moisture from vegetation. The rates of water use vary greatly by species of plants, depth to the water table or availability of moisture supply. In central California, summer evapotranspiration averaged 7.8 inches from old-growth red fir forest, 7.5 inches from young red fir forest, 6.2 inches from an area occupied by wild sunflower, and 4.0 inches from bare ground. Evaporation from snow in the 6-month period January through June 1959 totaled 1.7 inches in small forest openings and only 0.9 inch in the forest itself; however, snow evaporation in a meadow was 1-1/2 times that of the small openings, and on exposed ridgetops as much as three times that of the openings in the forest. In mid-June, a snow patch actually gained nearly 0.03 inch of water per day due to condensation. On the Black Mesa in Colorado, aspen used 20 inches of water, spruce 14 inches, and grassland 8.3 inches during a 3-year average period of June to October.

During five dry years (1952-57) in southern California when average rainfall was 20.6 inches at the lysimeter installation on the San Dimas Experimental Forest, annual evaporation losses of moisture from bare soil averaged 7.4 inches or about one-third of the rainfall. Evapotranspiration from a grass-covered lysimeter averaged 15.7 inches or about two-thirds of the rainfall. A similar evapotranspiration loss occurred on a plot of Coulter pine, but from four species of shrubs, evapotranspiration ranged from 16.9 to 18 inches. In the wet year of 1958 when 48.4 inches of rain fell, evaporation loss from bare soil was 8.7 inches, evapotranspiration from grass was 16.5 inches, from pine 25.1 inches, and from the shrubs 23.6 to 25.5 inches. The pine and shrubs each year used all available moisture in the 6-foot depth of soil. In contrast, about 10 inches of available water remained in the same depth of bare and grass-covered soil.

In the Manzano Mountains of New Mexico soil moisture recharge was not sufficient in any of 5 years of measurement to saturate a 30-inch soil profile having a cover of pinon pine and blue grama grass. All of the absorbed rainfall was used by the vegetation during the active growing season. Runoff from two ponderosa pine watersheds in Arizona was 10.6 inches for a 2-year period when precipitation totaled 51.4 inches. During the same period runoff was 3.6 inches on an alligator juniper watershed with 48.5 inches precipitation and only 2 inches on 2 Utah juniper watersheds where the precipitation was 42.1 inches.

Transpiration losses from Loblolly pine seedlings in a controlled environmental chamber were governed principally by available soil moisture. Moisture loss was highly correlated with radiation. Computations of

theoretical solar radiation on north- and south-facing areas in North Carolina indicate that the south-facing area should receive from 0.7 to 1.7 times more solar energy during the winter than the north-facing. During the spring and fall the south-facing slope should receive 0.4 to 0.7 times more energy and during the summer the two areas receive nearly the same energy. Thus, since these two areas receive nearly equal amounts of energy during the growing season, they might be expected to have the same rate of loss during the high evapotranspiration period. However, during the soil moisture recharge period, the south-facing watershed receives over twice the solar energy that is available to the north-facing slope.

During a 2-year period in Utah, water losses to the atmosphere by evapotranspiration from soil depths of 6 feet were 13.1 inches for aspen and 14.4 inches for mountain brush. The total volume of vegetation was almost 3 times greater in aspen than in mountain brush, and it is concluded that aspen is more efficient in water consumption or else it extracted more water at depths exceeding 6 feet. Total evaporation and transpiration losses aggregated 16.1 inches for aspen and 17.4 inches for brush, indicating that aspen sites have slightly more water available for streamflow. Calculation of evapotranspiration by the method of Thornthwaite and Mather for the period October 1957 to September 1958 totaled 12.8 inches at 8,200 feet elevation. This calculated value compares favorably with 12.0 inches measured for aspen and 12.9 for brush during the same period.

Included in erosional processes are studies of soil particle detachment or dislodgment, and sediment transport and deposition. On the Castle Creek experimental watersheds in central California, sediment concentration in the runoff increased markedly following the logging of 14.6 percent of the commercial timber volume. When discharges were 50 cubic feet per second from the 4-square-mile watershed, mean sediment concentration was 14 parts per million before logging and 38 parts per million after logging; but for discharges of 100 cubic feet per second the concentration of sediment was 40 parts per million before logging and 300 parts per million the first year after logging.

On the Fernow Experimental Watersheds in West Virginia, the effects of several timber harvesting practices have been measured in terms of turbidity (parts of soil per million parts of water) in the stream. Water from an unlogged area attained a maximum turbidity of 15 ppm; from the area of intensive selection cutting with carefully planned skidroads, 25 ppm; extensive selection cutting with planned skidroads, 210 ppm; diameter limit cut with unplanned skidroads but with water bars installed, 5,200 ppm; commercial clear-cut with unplanned skidroads, 56,000 ppm. The standard maximum for drinking water is 10 ppm. These differences are a reflection of skidroad location and maintenance. On the commercial clear-cut watershed 7.1 percent of the area was in skidroads, in contrast to 6.3 percent on the diameter limit watershed, 5.8 percent on the extensive selection cut watershed, and 1.9 percent on the intensive selection cut watershed. Seasons and durations of logging were also responsible for part of the differences.

An analysis of some 80 summer-type storm hydrographs from 6 different watersheds at the Coweeta Hydrologic Laboratory indicates that essentially all storm runoff from short, intense summer storms results from precipitation directly into the stream channel. Storm runoff as a percentage of storm rainfall varies between approximately 0.5 and 4.0 percent depending on the ratio of channel area to watershed area, depth and duration of rainfall, and interception losses. Time of concentration, time of peaking, and lag were determined for each plotted hydrograph. Lag is less affected by rainfall intensity and duration then time of concentration or time of peaking. For this and other reasons lag appears to be the most practical time element of the hydrograph for runoff prediction work.

Plans: Basic research will continue to be emphasized particularly in developing better understanding of the properties of soils, their hydrology and erosional characteristics; the physiology of plants in relation to water use and evapotranspiration losses; and the characteristics of snow and other weather phenomena. Better instrumentation and research techniques will continue to be sought.

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2. PREVENTION OF WATERSHED DAMAGE ON FOREST AND RELATED WATERSHEDS WMR

Problem: To develop and improve techniques of management of the several resources found on forested and related watersheds so that their use will not result in soil erosion, impairment of stream courses or water quality or in increased flood and sediment discharges.

Program: A continuing long-term program of applied research to understand and evaluate the changes in soils, movement of water into and over soil surfaces, and availability and use of water by vegetation which result from logging, road location, construction and maintenance, grazing, recreation activities and fire, for the development of new or improved management methods. This work is being done at the Northeastern, Central States, Southeastern, Southern, Rocky Mountain, Intermountain, and Pacific Northwest Experiment Stations and the Alaska Research Center in cooperation with seven other Federal agencies, and 12 State and 4 private agencies and organizations. The work involves about 15 man-years of Federally supported research.

Progress: Timber harvesting, particularly where large machinery is used, is receiving considerable attention in an endeavor to prevent watershed damage. In the Intermountain region, particularly Montana and Idaho, a total of 720 sites on granitic, basaltic, loessial, hard sediment, glacial silt, and andesitic soils have been studied. Soil samples from these sites have been analyzed for basic particle-size distribution and quantity and size distribution of water stable aggregates. From these and other data, criteria are being developed to aid engineers in their road development problems, particularly in connection with logging operations on steep slopes.

In southwestern Idaho, standards have been developed for spacing erosion control structures on skidtrails. On 20 to 30 percent slopes the maximum distance between structures should be 60-70 feet; on 40-70 percent slopes the maximum distance should be 40 feet. Structures should be closer together in ravines than on side hills, and where skidtrails are deeply gouged into mineral soil, structures should be closer than where there is vegetation left between the tractor tracks. Wider intervals for the same slope gradients may be used on basaltic soil than on the more erosive, granitic soil.

Construction of a logging road in one of the experimental watersheds of the Bull Run drainage near Portland, Oregon, has caused 6.2 percent of the watershed area to be disturbed as follows: Roadbed - 2 percent; backslopes - 1 percent; fill slopes - 3.2 percent. Precipitation with an intensity greater than three-quarter inch per hour created a small mudflow in the main creek with a suspended sediment load of 1700 parts

per million at the gaging station 0.6 mile downstream; an adjacent, untreated watershed remained clear with a maximum suspended load of 22 parts per million. During the 6-year preconstruction period, measured suspended sediment loads never exceeded 200 parts per million.

The management of grazing is another use of some forest lands requiring careful studies of management to prevent damage to watersheds. In central Utah, a study designed to measure the effects of seeding and subsequent grazing on infiltration, soil stability, and a number of vegetal characteristics and soil properties of a subalpine cattle range showed no significant differences in infiltration capacity or soil stability between the ungrazed seeded and native range sites. Infiltration capacity was 25 percent lower and soil stability significantly less on grazed than on ungrazed sites. There was no significant difference in soil organic matter between grazed and ungrazed sites but organic matter was significantly lower in the upper 2 inches of soil on seeded areas. Capillary porosity was significantly less on seeded sites than on native sites and also lower on ungrazed than on grazed sites. Noncapillary porosity was less on grazed sites than on ungrazed and reflects the effect of cattle trampling.

Two hardwood areas in the Arkansas Ozarks were sprayed for conversion to rangeland in 1947. This resulted in an average decrease of litter-humus (oven-dry) from 7,648 pounds per acre in 1948 to 4,238 pounds in 1959. On a comparable unsprayed area litter-humus increased from 7,147 pounds per acre to 9,568 pounds. During the same period, retention storage of litter-humus on the sprayed areas decreased from 0.10 inch per surface area to 0.036 inch, and the litter-humus remaining on the sprayed areas dried much more rapidly than did that on the unsprayed areas.

On the Gallatin Elk Range in Montana, the effect of two moderate-intensity summer rainstorms in eroding soil from ten 1/50-acre plots were analyzed in relation to ground cover and soil bulk density. Each of these storms produced about 0.5 inch of rainfall and had a maximum 5-minute intensity of 1.5 inches per hour. The least amount of soil eroded was 21 pounds per acre per storm from sites having a surface soil bulk density of 0.70 and a ground cover of 100 percent. Very little more soil was eroded from the ground cover density of only 70 percent, but as ground cover decreased below 70 percent the amount of soil eroded increased at a rapidly accelerated rate. Thus, a ground cover density of 70 percent is one requisite for preventing accelerated erosion on heavily trampled south-facing range sites in this area. As surface soil bulk densities increased above 0.70, the amount of soil eroded also increased. From the range sites studied, those having ground cover densities of less than 70 percent were usually associated with soil bulk densities greater than 1.00. Under the conditions provided by ground cover densities of 70 percent or more in combination with soil bulk densities of 1.00 or less, no more than 50 pounds of eroded soil per acre should be expected from storms described as above.

Plans: Research on the prevention of damage to watersheds will be continued at about the present level on methods of logging, road construction, grazing and recreation management. More and more detailed study will be given to soil characteristics, precipitation patterns, and cover requirements in the development of management practices.

Publications: Road and Slope Characteristics Affecting Sediment Movement from Logging Roads. Harold F. Haupt. Journal For. 57: 329-332. 1959.

A Method for Controlling Sediment from Logging Roads. Harold F. Haupt. Intermountain Forest and Range Exp. Sta. Misc. Pub. 22. 1959.

3. REHABILITATION OF DAMAGED FOREST AND RELATED WATERSHEDS WMR

Problem: To develop rehabilitation measures and improved management practices to restore soil and other mantle materials and satisfactory surface flow and streamflow conditions on damaged and unstable forest and related watersheds.

Program: A continuing program of both long- and short-term studies aimed at the development of methods of establishing, improving, and managing vegetation cover supplemented by wise use of structures and other mechanical aids to stabilize soil and water conditions at a satisfactory level. Seven regional forest experiment stations: Central States, Intermountain, Lake States, Northeastern, Pacific Northwest, Southeastern, and Southern, are engaged in this work. Cooperators include three Federal agencies, four State, and one municipal organization. About 16 man-years of professional Federal man-years are involved.

Progress: Disturbances in connection with logging operations and road construction activities have created serious watershed conditions in mountainous areas. To establish a grass cover on logging roads, it was found that hand broadcasting of seed without seedbed preparation gave as good results on granitic soils as did seeding followed by harrowing, hand broadcast seeding followed by scarifying to a depth of 12 inches, or scarifying followed by hand broadcasting of seed. Fertilizing with a commercial 20-20-0 fertilizer at a rate of 200 pounds per acre had no significant effect on the establishment of plant cover. A woodchip mulch reduced significantly the number of grass plants established and the percentage of live plant cover on roadbeds but had no effect on height growth.

On the White Mountain National Forest, N. H., disturbed areas have been seeded to grass at rates of 30 pounds per acre and with 2,000 pounds of lime and 600 pounds of 10-10-10 fertilizer. This treatment has resulted in good to excellent cover density and height growth, and has restricted erosion. Untreated plots and plots seeded but unfertilized had poor or no vegetation during the first growing season. The necessity of applying fertilizer in seeding operations on roadbanks was also established on the Mt. Hood National Forest in Oregon.

Streamflow records at Union, South Carolina, from a 13-acre rehabilitated watershed show that stabilizing 3.5 acres of gullies with grass and pine has reduced peak discharge, and sediment trapped in the weir has decreased from 66 tons per acre per year before treatment to .128 ton per acre per year after treatment. Erosion is still active in isolated places in the watershed, but most of the eroded material is deposited within the watershed because both the rate and volume of overland flow have been reduced by stabilizing treatment.

Twenty-two years of streamflow records from two watersheds in northern Utah, one having no history of plant cover depletion, or floods, and the other having a history of mudrock floods but later seeded, contour-trenched, and protected from grazing, were analyzed and compared. The time trend analysis of discharges from Parrish Creek (the reseeded watershed) compared with those from Centerville Creek (the checked watershed) showed that Parrish Creek streamflow decreased 2.70 inches over the 22-year period for an annual decrease of 0.12 inch. Eighty-three percent of the total decrease in streamflow occurred in the first 11 years after seeding. The trend of decreased annual discharge from the restored Parrish Creek watershed has also been accompanied by a delay in the date of maximum daily discharge. During the early period of record, Parrish Creek tended to reach its maximum daily discharge about 3 days earlier than Centerville Creek, but in the later years the maximum discharges have occurred about 3 days later than Centerville Creek. Furthermore, sedimentation, which was such a great problem in 1930 during the mudrock floods, has been virtually eliminated.

Studies in central Utah reveal that snowmelt runoff eroded 2.05 cubic feet of sediment per acre from a range watershed which is being restored by natural means, but no sediment was eroded from a similar watershed whose plant cover was restored artificially. No summer storm runoff occurred from either watershed in 1959.

Natural rehabilitation in addition to pine planting is now taking place on the watersheds which had been farmed and heavily grazed at the Coweeta (N. C.) Hydrologic Laboratory. White pine planted 5 years ago now stands more than head high and natural yellow poplar regeneration is dense over a large portion of the area, indicating that land too poor to support cultivation or grazing will still support excellent forest growth. After 6 years' freedom from grazing, however, the woodland area still contains little low vegetation as compared to the dense growth exhibited in fenced exclosures.

Plans: To continue to give emphasis in this program to problems associated with rehabilitation of gullied areas; to maintain other research at present levels.

Publications: A Method for Controlling Sediment from Logging Roads. H. F. Haupt. Intermountain Forest and Range Exp. Sta. Misc. Pub. No. 22. 1959.

1958 Phase of Pleasant Creek Watershed Restoration Evaluation Study. R. Thompson and R. O. Meeuwig. Intermountain Forest and Range Exp. Sta. Unnumbered report. 1959.

Sites and Seedling Grades Influence Loblolly Growth. S. J. Ursic. Southern Forest Expt. Sta. Southern Forestry Notes No. 122. July 1959.

4. WATER YIELD IMPROVEMENT FROM FOREST AND RELATED WATERSHEDS WMR

Problem: To improve in quality, amount, rate, and timeliness of flow the water yielded from the major types of forest and related lands for domestic, agricultural, industrial and recreational use.

Program: A long-term research program involving studies of the manipulation of vegetation and the control of water use by vegetation; artificial control of snow accumulation, sublimation and melt; and the diversion and control of water for ground-water recharge is being carried on by the Intermountain, Northeastern, Pacific Northwest, Pacific Southwest, Rocky Mountain, and Southeastern Forest Experiment Stations. Cooperators in this work include three other Federal agencies, four States, and one municipality. About 21 man-years of professional Federal time go into this research.

Progress: The processes of interception, evapotranspiration, and snow accumulation and melt are the main factors involved in research in water yields on forest lands. In central California, the removal of brush by bulldozing in converting brush fields to pine is credited with saving 3 inches in annual summer water losses. An estimated additional 2 inches of water per year was saved through reduction in interception, transpiration, and evaporation from snow during winter and spring. Thus a total reduction of 5 inches water loss annually is estimated for a soil depth of 4 feet based upon 2 years of records. In southern California, treatment of 40 acres of side slopes with deep soil in a 100-acre watershed by spraying the brush and forb cover resulted in an estimated increase in streamflow of 5.6 acre-feet for the period June 1, 1958, through September 30, 1959. This increase was obtained in spite of the fact that rainfall during this period was considerably below normal.

The woodland riparian vegetation was cleared from approximately 40 acres along the main channel of Monroe Canyon in the San Dimas Experimental Forest in California, out of a total watershed area of 875 acres. Stump sprouts, brush seedlings, and forbs on the cleared area were sprayed with phytocides in the spring of 1959. Although rainfall was only about 50 percent of normal during the 1958-59 rainy season, streamflow was continuous from the treated watershed, whereas usually with such deficient rainfall streamflow ceases during the normally dry season. During the period May 1, 1958 through September 30, 1959, the estimated increase in streamflow yield for Monroe Canyon due to the treatment was about 38 acre-feet.

On the Fernow Experimental Forest in the central Appalachian hardwoods of West Virginia, 4 different cutting practice levels showed marked effect on water yield the first year after logging. On a commercial clear-cut

watershed where 9,000 board feet were removed per acre, the water yield increased 3.08 area-inches; the diameter limit watershed with 4,300 board feet per acre removed increased 1.84 area-inches; the extensive selection watershed with 3,500 board feet per acre removed increased 1.42 area-inches; and on the intensive selection watershed with only 1,800 board feet per acre removed the increase in water yield was only 0.31 area-inch.

The heavier the cut, the greater the increase in water yield was emphasized by the fact that streamflow from the commercial clear-cut area more than doubled for the May-October period. Two years of record have been taken on this commercial clear-cut watershed and there was a noticeable decrease in the amount of yield in the second year. The rapid sprout and herbaceous growth following cutting is in part the cause of this decreasing effect. Some difference is also due to differences in amounts of precipitation between the two seasons.

Several studies have been conducted to control snow accumulation and melt by manipulating cutting patterns and densities of timber stands or through the use of artificial barriers to induce drifting. Alternate strip cutting which removed the trees from 40 percent of a 714-acre subalpine forest in Colorado increased water yield 183 acre-feet in 1959. This amounted to 3.1 area-inches as compared to 4.2 area-inches for 1956, 3.4 inches for 1957, and 2.1 inches for 1958.

In central Utah, a snowdrifting fence 300 feet in length was constructed in 3 sections of 14, 18, and 21 feet in height. The 18-foot high section was damaged during the winter and its effectiveness was reduced to that of the 14-foot high section. Water stored in the drifts induced by these fences is shown below by dates:

Date	Fence height (feet)		
	14	18	21
	Cu. Ft. of water per lineal foot of fence		
April 15	334	338	419
May 20	270	244	362
June 15	Tr	Tr	47

Drifts behind the 14- and 18-foot sections persisted until June 15, while that behind the 21-foot section persisted until June 20. The snowpack on adjacent untreated areas had almost disappeared by April 15. Considering that the construction cost of the 21-foot fence was almost twice that of the 14-foot fence, it appears that the lower fence is more practical for construction on this wind-swept area. Measurements behind a 16-foot high fence at another location showed that this fence was more effective in 1959 when snowfall was below normal than in 1958 when snowfall was above normal. On May 29 the induced drift stored 195 cubic feet of water per linear foot of fence and the drift persisted until June 14, while snow on adjacent areas disappeared on May 31.

In Colorado it was found that natural snow accumulation zones with a low snowfence on the windward edge caught about 1-1/2 feet more snow per month than did similar zones with no fence.

Plans: Concentration in research will be placed on two areas of water yield improvement: manipulation of forest cover to reduce the consumption of water by the forest trees, and control of the accumulation and melt of snow in the forest, subalpine and alpine areas to reduce peak flows and extend the period of usable flows into the dry seasons. To these ends the effort will be increased.

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5. SOIL IMPROVEMENT FOR FORESTRY WMR

Problem: To develop methods and techniques and determine practices for improving soils to increase success of planting trees and other vegetation, to increase growth and production, to improve infiltration and percolation of water and to reduce the incidence of insect and disease infestation on forest and related watersheds.

Program: A continuing program of long- and short-term research devoted to soils and their formation and aimed at improving fertility, composition, structure and drainage under different situations of origin, environment and management. This research is conducted by the Southern, Southeastern, Lake States, Pacific Northwest, Intermountain, and Northeastern Forest Experiment Stations in cooperation with Agricultural Research Service, several State agencies and universities and private industries. About 5 professional Federal man-years are involved.

Progress: Field examination, measurement, sample collection, and photographic record were made of important forest humus types in the northern forest region of the Lake States. Emphasis has been placed on delineation of "duff-mull" types and development of suitable criteria for field identification.

At the Union Research Center in South Carolina, litter continues to be added to the soil of old-field pine stands at an accelerated rate and organic matter continues to be added to the soil as decomposition occurs. Hickory litter decomposes more rapidly than the oak; pine litter is decomposing at a slow rate.

In northern California erosion and dispersion ratios and surface aggregation ratios have been determined from soil samples taken at 168 sampling sites under constant conditions of elevation and precipitation. Statistical analyses were made of the ratios relating them to geology, vegetation, elevation, and geographic location. Prediction equations utilizing these factors suggest that parent material (geology) is by far the most important single factor.

In the Lake States and the Southeast studies are being started to better understand and then to improve the deep organic soils found in wetland forests. These soils are very important both productively and hydrologically.

Plans: To continue the program at a somewhat increased level of effort in order to study the effects of water control in wetland forests; to study forest soil formation as influenced by soil organisms and vegetation cover; and to study the needs and use of fertilizers in forest and range production.

6. PILOT SOIL SURVEYS FOR NATIONAL FORESTS WMR

Problem: Determine the usefulness of soil identification and mapping and the interpretation of soils information in the preparation of plans for multiple-use management of national forest lands and to develop techniques and criteria for multiple uses.

Program: A limited-term program of research on the interpretation and use of soil survey information on lands managed for forestry, grazing, recreation, water production, road location and construction, and other uses. This work is being done at the Intermountain, Rocky Mountain, and Pacific Southwest Stations in cooperation with the Soil Conservation Service, California Agricultural Experiment Station, and several other State agencies. About three man-years of professional Federal time is going into this work.

Progress: Pilot soil surveys have continued in all national forest regions in continental United States, and on several areas the multiple-use management plans have been prepared. Four training schools were held for national forest administrators in the use of soil surveys; a soils handbook was prepared for in-service use; and strong emphasis was given to the development of criteria for interpreting soils information in engineering problems. Additional pilot areas are being surveyed.

In New Hampshire, studies are underway to classify and map in detail on a watershed basis those soil morphological characteristics which are important to watershed management and forest management research. Soil types and phases were combined into undifferentiated groups which were homogeneous as to soil properties important to water relationships and timber growth. Mapping units include these groups as subdivided into classes or subdivisions of texture, depth to bedrock, natural drainage, surface stoniness, slope gradient, and parent or underlying material. Aspect, position on slope, and exposure were also considered pertinent. Average size of delineated area was about 80 acres.

Plans: The soil survey program will be continued in all regions on a slightly expanded scale and new work will be begun in Alaska. Development of interpretive criteria for applying soil survey information to national forest multiple-use management will be continued.

Publications: A Soil Survey of Forest Land. Lloyd E. Garland, Robert S. Pierce, and George R. Trimble, Jr. Jour. Soil and Water Conservation 14: 199-204. 1959.

III. WATER MANAGEMENT

1. IRRIGATION REQUIREMENTS AND PRACTICES SWC

Problem: Determine the soil physical properties which control or modify the water requirements of specific crops at different morphological stages of development and develop improved and more efficient water management practices.

Program: A continuing program involving the development of basic principles, theories, and applications, including the main effects and interactions of soil moisture movement on water and ion uptake by plants in response to both metabolic activity within plant roots and atmospheric conditions above the plants. The research involves work in twenty states, in cooperation with state agricultural experiment stations, and about eighteen professional Federal man-years annually.

Progress: The response of 25 double-cross corn hybrids to irrigation was evaluated in Mississippi. The unirrigated hybrids produced 76 to 130 bushels of corn per acre while the irrigated hybrids produced 79 to 142 bushels of corn per acre, showing that genetic constitution produced marked differences in efficiency of water use. Dixie 55, containing cytoplasmatic male sterile characters, was the highest yielder under irrigation, indicating no detriment to efficient use of water resources from using this character for breeding purposes.

The increase in production of forages in Virginia from irrigation ranged from 1000 to 4000 pounds of dry matter per acre. Approximately 10-inches of irrigation water were required. Larger increases in yield were obtained from irrigating mixtures containing shallow rooted legumes, such as ladino clover or white clover, than from deep-rooted legumes such as alfalfa.

During 1959, when rainfall was adequate in amount and distribution, there was no significant response of flue-cured tobacco to irrigation at Tifton, Georgia. There was a significant increase in yield from 250 pounds per acre of 6-3-24, in addition to the basic fertilization, indicating nutrition deficiencies in the irrigation experiment. Tobacco quality was not adversely affected by additional fertilizer.

The annual yield of St. Augustine grass grown on highly fertilized Davis fine sand was not affected by depth to water table in the range between 12 and 36 inches at Ft. Lauderdale, Florida, in 1959. Evapotranspiration was markedly affected, however. When water tables were 12, 24, and 36 inches below the soil surface, 30, 27, and 20 inches of irrigation water were required, respectively.

At Weslaco, Texas, more than 2 bales of cotton were produced in a relatively wet season with one irrigation (1958), and in 1959, a relatively dry season, there was no response to irrigation with depth to water table in the experimental area varying from 5 to 7 feet during the growing season.

In the period from May 4 to December 1, 1959, salt concentration increased at most depths to 5 feet, and in all but the frequently irrigated wet treatment. The change was smallest in the surface 2 feet, and greatest in the 3- and 4-foot depths. Furthermore, the degree of salt accumulation was closely correlated with the amount of water applied as irrigation plus rainfall. With decreasing amounts of applied water, salt concentration increased and was greatest in the 3- to 5-foot depth on the nonirrigated plots. The magnitude of increase in this depth range for the nonirrigated plots ranged from 1.0 to 1.5 millimhos per cm. for the season. These results indicate upward movement of salt and water from the water table and the eventual need for leaching on the less frequently irrigated treatments either naturally by rainfall or intentionally with irrigation water. Nevertheless, results of these experiments are highly significant from the standpoint of making most effective use of limited water supplies in the Lower Rio Grande Valley.

Moisture use rates of grain sorghum increased as irrigation frequency increased. Unirrigated sorghum used 0.11 inches per day while 0.18 inches per day was used at the highest irrigation frequency. Grain yields and stover yields were increased and lodging was reduced as irrigation frequency was increased. Yields per acre were about 10 percent higher where 20-inch rows were used than where the conventional 40-inch rows were used. At 4:00 p.m. soil temperatures were 4 to 5° C. cooler at 4-inch depth between 20-inch rows than between 40-inch rows.

At Reno, Nevada, seasonal consumptive use of alfalfa grown in lysimeters with water table at 2, 4 and 8 feet, and with no water table in coarse-, medium-, and fine-textured soils ranged from 32.1 to 47.7 inches. Average daily use for the same treatments ranged from 0.25 to 0.37 inches. Seasonal consumptive use decreased as depth to water table increased on nonirrigated treatments with a maximum difference between the 2- and 8-foot water tables of 11 inches on the medium-textured soil. Surface irrigated treatments with water table gave variable seasonal consumptive use values with the 4-foot water table depth being roughly 6 to 8 inches less than the 2- or 8-foot depth on coarse- and fine-textured soils. In all cases, the no-water-table treatments used less water than the treatments with water tables. Yields generally decrease with depth to water table in the nonirrigated treatments but magnitude of differences was small. Maximum range in yield for all treatments was 7.4 to 9.9 tons per acre.

Studies on a model section of an irrigation well were completed at Fort Collins, Colorado. Aquifers ranged from very fine to coarse sands with various uniformity coefficients.

A sprinkler irrigation study is being conducted at Boise, Idaho, to determine the effect of sprinkler pattern on field irrigation efficiency and the relationships between field irrigation efficiency versus sprinkler pattern, wind velocity, humidity, temperature, irrigation period, and related factors. Data indicate that the Soil Conservation Service pattern efficiency method looks the most promising at the present for relating sprinkler pattern coefficients to irrigation efficiency.

Analysis of the data obtained in a study at Logan, Utah, to determine the effect of lay-flat tubing shape on friction loss has been made. Some of the results obtained are available in a curve relating the change in head loss due to a change in velocity distribution caused by the shape of lay-flat tubing as compared to a round pipe. An additional curve has been developed to show the effect upon head loss of both change in velocity distribution and relative roughness as caused by the shape of the tubing.

A summary of earlier and more recent studies on the use of a vortex tube as a sand trap has been made at Fort Collins, Colorado. The purpose of the sand trap is for removal of bedload from canals by ejection of larger size material traveling as bedload. Straight tubes were found to operate as well as tapered ones. The actual shape of the tube was not important, providing this shape was such that the material was not allowed to escape back into the channel. A pipe with a portion of the circumference removed seemed to operate as well as other prefabricated shapes. Under these specifications, vortex tubes can be expected to remove approximately 90 percent of material greater than 0.8 mm., 80 percent of that in the size range of 0.6-0.8 mm., and 70 percent in the range of 0.4-0.6 mm. For material smaller than 0.3 mm., the efficiency will be very low since much of this material will be in suspension and will not be trapped.

Plans: This work will continue at approximately the same level. Continued effort will be made to find techniques that will give increased irrigation water use efficiency.

Publication: Evapotranspiration Concepts for Evaluating Sprinkler Irrigation Losses. E. H. Wiser, J. van Schilfgaarde, and T. V. Wilson. N. C. Expt. Sta. Jour. Paper 1100.

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2. HYDRAULICS OF SURFACE IRRIGATION SWC

Problem: To improve the efficiency of applying irrigation water, through furrows, on sloping lands and on level land.

Program: A continuing program utilizing basic engineering research techniques in both laboratory and field studies. Analysis of the hydraulic design factors of surface irrigation application practices results in new concepts of grade tolerance, row shape, furrow design, etc. Use of model techniques facilitate this type of study by providing greater control of the variables. The work involves about 3 Federal professional man-years annually.

Progress: In determining means of improving the efficiency of applying irrigation water, furrow studies in Missouri showed that the rate of advance of an irrigation flow varied from 0.011 feet per second for conventional semi-V shaped furrows to 0.027 feet per second for flat bottom furrows. In other words, it took one hour longer for water to travel 800 feet in the conventional than in the flat bottom furrow. The intake rate varied directly with the stream width. Similar studies in Alabama on irrigation furrows resulted in development of an empirical design relationship which affords a means of estimating the stream size and application time for a furrow irrigation system prior to land forming. Full use of this procedure is dependent upon further knowledge of the hydraulic

characteristics of low flows in furrows.

Using a sand-glycerine model technique, Ohio studies showed that the measured positions of the free water surface on a series of draw down studies deviated from those predicted by various mathematical solutions by less than 10 percent. Further study of the flow phenomena in subsurface drainage will be carried out on a 557 unit variable resistance network developed to permit rapid solution of the flow problems through use of electrical flow principles.

A laboratory study has been initiated at Colorado State University to determine the hydraulics of flow in small rough channels. Basically, these studies are aimed at relating a description of furrow roughness and furrow shape to a resistance coefficient for flow in furrows, to determine the effect of infiltration on the resistance coefficient in furrows, and to develop methods for determining the resistance coefficient for nonuniform flows. Preliminary data have shown that the resistance coefficient changes with depth of flow. Mannings "n" decreases with increasing depth and at large depths approaches a constant minimum value.

Additional studies on the larger trapezoidal flume were made at the Fort Collins Hydraulic Laboratory. These were of two types: One having side walls at 60° from the horizontal with an 8-inch throat width at the base; the other having a throat width of 1 foot with side walls having a 1.25 to 1 slope (1.25 horizontal to 1 vertical). Rating tables for both flumes have been prepared. These ratings were prepared for the 2 to 1 contraction design. The degree of contraction is defined as a ratio of the bottom width of the approach section to that in the throat section. The discharge for the 8-inch 60° trapezoidal flume ranges from 0.24 c.f.s. with a head of 0.20 feet to 18.25 c.f.s. with a head of 2.20 feet. These tables are prepared for free-flow discharges with the head measured in a vertical direction from the base of the flume. The 1-foot, 1.25 to 1 flume can measure flows as low as 0.5 c.f.s. to as high as 60 c.f.s. The side slope of this flume is the same as those used in medium-sized lined irrigation ditches, and can be constructed as an integral part of the lining. With a 3 to 1 contraction, there is less flow for a given head than for the 2.5 to 1 or the 2 to 1 contraction; however, this difference is slight, and amounts to approximately 4 percent between each increment of contraction.

The effect of submergence was also studied. Submergence is defined as the ratio of depth at some point downstream from the control section to that at the upstream gage point. A correction curve has been developed to adjust for submerged flow conditions. Submerging begins to become a factor for values exceeding 60 percent; however, there is only a 3 percent deviation from the free flow relationship at 80 percent submergence. Since this is within the usual expected error of measurement with a flume, a correction may not be needed until submergence exceeds 80 percent.

The improvement of surface water control through land forming and smoothing practices was under continued study in the Mississippi Delta region of Louisiana, the Coastal Plain and Piedmont areas of Virginia,

the Lakebed area of Ohio, and in the Red River Valley area of Minnesota.

At Lincoln, Nebraska, major progress was made in studies of the hydraulics of flow in furrows as related to erosion from natural rainfall. Time of concentration of water in the furrow was almost double for broad furrows as compared to narrow ones and was about constant for slopes less than 0.6 percent. As slope increased to 2.5 percent, time of concentration gradually decreased to about 50 percent of that for flatter slopes. Velocity of flow in the furrow was approximately constant with position down the furrow and was linearly related to runoff as was furrow detention. Soil erosion was directly related to rate of runoff and appreciable erosion occurred on slopes of 0.6 percent with a high intensity storm. Rate of soil loss was extremely high on the 2.5 percent slope. Infiltration rate was reduced and runoff and erosion greatly increased in furrows which had been traversed by tractor tires. This appears to be a very significant factor in runoff-erosion relationships under graded furrow conditions.

Plans: This work will be continued at about the same level except at 2 or 3 locations where additional basic studies will be undertaken.

Publications: Measurement of Discharge Using Flat Trapezoidal Flumes. A. R. Robinson. Col. State Univ. Res. Found. Civil Engr. Section, CER 59 ARR57. January 1960.

Flow Regimes in Surface Irrigation. Lloyd E. Myers, Jr. Agric. Eng. 40(11): 676-683. Nov. 1959.

Soil Erosion and Its Control Under Furrow Irrigation in the Arid West. J. Stephen. Mech. Agric. Info. Bul. No. 184: 1-6. August 1959.

3. DRAINAGE REQUIREMENTS AND PRACTICES SWC

Problem: Determine drainage requirements of soils and crops for improved design of drainage systems and application of better practices of water control which will provide a more favorable environment for crops; allow for more efficient performance of farming operations such as tillage, cultivation, and harvesting; and conserve soil and water resources. Improved methods and materials are also needed to meet the multiple drainage problems of the nation.

Program: A continuing program involving the development of basic principles, theories, and applications carried on in fourteen states in cooperation with State Agricultural Experiment Stations and involving about 10 professional man-years annually.

Progress: In order to evaluate drainage requirements of plants, soybeans were grown in buried steel tanks under natural sunlight conditions in North Carolina. Water treatments included water table control at 6, 12, 18, 24, and 30 inches below the soil surface. Half of the tanks received natural rainfall but rain was excluded from the other half by a movable shelter. In both cases, yields were highest where an 18-inch water table

was maintained. Where rainfall was excluded, however, yields were reduced. This reduction was probably due to the higher salt content of the surface soil where leaching by natural rainfall was reduced. Where water tables were maintained 6-inches or 12-inches below the soil surface, oxygen diffusion rates through the liquid films of water were sufficiently low to be causative factors of poor plant growth.

A new type of surface drainage system was installed in Louisiana cane areas in 1957. Utilizing a Louisiana cotton area type of drainage layout, together with precision land grading, permitted removal of extra field ditches and facilitated maintenance of the remaining ditches. Each row, having a grade of .08 feet per 100 feet, drains the full length of the field into a broad, flat collection ditch having 8:1 side slopes that will permit crossing with heavy equipment. Absence of conventional ditches facilitated Johnson grass control. Cane yields in 1959 averaged 34.13 field tons, which is comparable with yields from conventionally drained fields.

Near Gainesville, Florida, preliminary tests on the application of plastic lined mole channels for combined drainage and subirrigation were made on Leon sands. Under saturated sand the present methods of lining were found to be inadequate. Failures in proper shaping of the liner and resultant sand entry caused stoppage in about 45 percent of the lines. It appears that a positive seam for the plastic liner is essential in this soil type. Additional study of perforation size and shape may also be essential for use under saturated sand conditions.

In the heavy textured Delta soils of Louisiana, plastic lined moles lowered water tables one foot in 48 hours for an effective distance of 28 feet from the drain. Sugar cane yields showed an increase of approximately two tons in the mole drained areas after the first 14 months of test.

A detailed study of the loading characteristics of plastic lined mole drains showed that the thin walled (0.010 inch to 0.030 inch) materials now under study have little influence on the stability of the drain under surface loads. The arching action of the soil was the main factor determining the drains' resistance to deformation by surface loads.

Check of flow rates from lined and unlined moles installed near Ithaca in 1957 showed flows ranging from 7.5 to 16 gpm. Previous checks on one soil showed maximum flows under a one-foot head of 3 gpm for unlined moles and 18 gpm for lined moles. This indicates little change in drain efficiency over the three-year test period.

Work was initiated in early 1960 at Columbus, Ohio, to develop a technique of making a continuous seam in forming plastic liners for mole drains to overcome the difficulties in sediment entry and shape change experienced in various field tests of unsealed lines.

Plastic lined drains were installed in seven different locations beginning in May last year. The main installations consist of nine lines 250 to 400 feet long with spacings of 20 to 40 feet. In addition, several field trials were also installed, as follows: two in California; one in Nevada; one in Logan, Utah; and one in Grand Junction, Colorado. Some of the results obtained during the first season have indicated that during installation there tends to be a hump in the drain near the outlet end of the lines. However, after the first 10 to 15 feet of installation, grade alignment appears to be satisfactory on land previously leveled as found under Western irrigated conditions. The problem of sand and silt entering the plastic drain, resulting in clogging, needs further attention. Tubes for erosion protection should be installed at the outlet as soon as possible after installation. Extreme care should be taken when cutting ditches or dykes over newly installed lines. Where ditches or dykes must be installed, they should be built immediately to prevent the soil from drying in large fractured chunks that tend to crush the lines when the tractor wheels cross them. More information is needed on optimum soil moisture for installation, management practices immediately after installation, such as soaking the lines to compact the soil, dragging, etc., and on methods of deeper installation. Improvement is also needed on the installation machine to avoid frequent breakdowns.

In one of the test installations the plastic tile was placed in a shallow silt loam soil overlying clay. The depth of the surface soil varied from 18 to 24 inches. This site was irrigated with water of good quality containing 225 parts per million total salts. Analyses of the quantity and quality of the tile effluent during the season showed that total salts in the profile should have been reduced by more than half to a depth of 15 inches.

A new tile drainage system installed in a 30-acre field in the Lower Rio Grande Valley having soil classified as Hidalgo clay loam, saline phase, was evaluated during the past year. The salt content in the soil was measured in April 1958 and in April 1959. During the first year of operation of the drainage system, 12 inches of irrigation water were applied and 30 inches of rainfall were received. At the time of installation, the water table at the midpoint between drains was approximately 1.7 feet above the minimum flow line in the drains. At this time, rate of flow was 8 gallons per minute per mile of drain. When the water table rose to 3 feet above the flow line, midway between drains, the flow rate was 18.9 gallons per minute per mile of drain. During the first year's operation, 35 to 43 tons of salt were removed from the 6-foot profile. Volume of drain flow for the period was 7.2 acre-inches per acre and the salt content represented approximately 30 tons of dissolved salts per acre. During the first year's operation, this drainage system could be credited for approximately 75 percent of the reduction in soil salinity.

Procedures have been outlined for establishing interpretive soil groupings for the Newlands Project, Nevada drainage investigations. The soil groupings were made so that any project or problem area can be similarly classified for investigation, planning, and system design studies. These procedures are based on soil surveys utilizing series, type, and phase

classification, stratum surveys, and other available information.

Development of design criteria for the drainage of sloping wet lands is dependent upon full analysis of the moisture transmission characteristics of the soil profile. Data from experimental sites in Vermont are being analyzed with an electrical resistance network that permits a study of many combinations of drain depth, drain spacing, depth to impervious layers, etc., on the basis of the measured soil moisture transmission characteristics of the test area. This permits the inexpensive texting of a variety of drainage system designs. The most effective design will then be installed and field tested to corroborate the laboratory analysis. This approach provides a basis for solving similar interception drainage problems over a wide area.

Hydrological studies of ground water in the Red River Valley of North Dakota have shown that water table fluctuations are directly affected by rainfall. In the lacustrine area, water table is more sensitive to rainfall than in the glacial drift area. Results obtained from piezometer installations show a definite artesian pressure at a depth of 20 feet in sloughs, creek bottoms, and low-lying areas. In the remainder of the area, water levels of the 20-foot piezometers fluctuate similar to that of the water table. Pressure measurements were also made on many of the domestic artesian wells in the area. When plotted, the piezometric water surfaces are below the ground surface adjacent to the Red River and also in the southwest portion of the study area. However, between the Red River and the southwestern section, the piexometric surface rises above the ground surface and in this area nearly all of the domestic wells are flowing.

As supplementary data to drainage investigations in the area, chemical analyses of various waters have been made. These analyses indicate close relationship between artesian waters of the Dakota sandstone formation and the saline areas in the glacial drift soils, indicating that aquifers may exist in the glacial drift between the Dakota sandstone formation and the ground surface. This was not true in the lacustrine areas where the chemistry of the water is similar to that of the surrounding soil.

Studies in the Lower Rio Grande Valley to characterize the salinity (hot spot) problem in the dryland area have continued. There appears to be no significant variation in water table elevation which can be correlated with occurrence of salinity in the soil surface. Approximately 375 observation wells and piezometer batteries have been installed in the study area to evaluate the water table.

Fluctuations of the water table associated with occurrence of local high intensity rainfall indicate the water table to be one of the major factors contributing to the salt salinization in the area. The results indicate for control procedures some measure of control over the water table which may rise near the surface in the area would be the first priority in solution of this problem.

Plans: In general this work will be continued at about the same level during the coming year. However, the development work on the mole lining equipment will be intensified within budgetary limits to bring this practice into field application as quickly as possible.

Publications: Discussion of Drainage of Agricultural Lands Using Interceptor Lines. W. W. Donnan. Amer. Soc. Civil Eng. Proc. Paper 1964, IR-1. March 1959. A. R. Robinson. Amer. Soc. Civil Eng. Proc. - Jour. of the Irrig. and Drainage Div., Discussion No. 2327, IR-4, Dec. 1959.

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Land Forming--An Accepted Drainage Practice. Walker, Phelps, and J. H. Lillard. Agr. Eng. 41(1): 24-27. January 1960.

4. WATER CONTROL AND CONSERVATION SWC

Problem: The accretion and depletion of soil moisture need to be regulated, and criteria and practices developed for conserving and more efficiently utilizing moisture supplies for sustained crop production in conservation farming and ranching systems. Moisture conservation, erosion control and other benefits which result from land leveling, parallel terracing, benching, and other mechanical land forming practices need to be evaluated and criteria and solutions to management problems developed for more successful land forming practices.

Program: A continuing program of basic and applied research involving methods of control of soil physical factors that determine moisture intake, retention, and transmission characteristics, and of land conditioning and land forming for efficient use of soil and water resources. Work is underway in about 12 states, in cooperation with State agricultural experiment stations. It involves about 16 professional Federal man-years annually.

Progress: Major effort was continued on development and evaluation of land forming and other mechanical practices for moisture conservation. At Bushland, Texas, runoff in the conservation bench system was negligible during the growing season in 1959, and sorghum yield on the benches was equivalent to continuous sorghum yield. Alfalfa and forage sorghum yields on benches were also very low. At sorghum seeding time, the benches contained about 1 inch less available water than contributing areas and this combined with the higher seeding rate kept yields low. At Mandan, North Dakota, grain yields were increased about 7 bushels per acre where a plastic covered distributing area was used in this very dry year. No appreciable runoff occurred from contributing areas of grass, fallow or wheat and yields were generally less than 15 bushels per acre on benches with these contributing areas. At Hays, Kansas, runoff occurred from numerous storms onto the benches and total runoff varied from 1.8 to 5 inches from 25 inches of precipitation. Grain yields were excellent, ranging from 1,800 to 2,600 pounds per acre of sorghum grain on the

benches and about 1,750 pounds per acre on the contributing area in a wheat-sorghum-fallow sequence. Average yields were 50 percent higher on the filled side of the bench than on the cut with the nondisturbed area intermediate. At Akron, Colorado, no runoff occurred onto the benches and yields of sorghum were equivalent to continuous sorghum yields elsewhere on the farm.

Crop yield data obtained from land forming experiments on the heavy textured Coastal Plain soils of Eastern Virginia showed some yield decline the first year after forming. Yields from fill areas, however, were significantly higher than from cut areas. Also, yields were less affected on plots where a minimum of soil was moved. Results showed that these yield depressions can be overcome by several years of good crop and tillage management.

Investigations of land forming techniques for Piedmont River bottom areas in Virginia indicated that approximately 635 cubic yards of soil per acre must be moved to provide large farmable areas having uniform slope gradients. Primary earth moving required 6.8 hours per acre, while final smoothing to grade took 2.6 hours per acre. Construction cost was approximately $115 per acre, plus six man hours per acre for layout and supervision. The near zero natural slope of the Piedmont River bottoms requires movement of more soil to attain uniform row gradients than is required on the Coastal Plain areas.

A "soil hardness indicator" was developed to measure the resistance of the soil to tillage following land forming. The indicator consists of a soil chiseling tool with depth control, a hydraulic cylinder, and a continuous hydraulic recorder that measures the resistance of the soil to tillage as the machine is pulled across the plots. Virginia results with the indicator showed that shallow tilling or scarifying of the soil immediately after forming land reduces the power needed for tillage to an 11-inch depth by 38 percent.

Tests in Minnesota to determine the effect of land forming on soil moisture and temperature levels showed that neither slope length nor grade had a significant effect within the range of conditions tested (slopes 640 feet vs. 320 feet and grade 0.2 percent vs. 0.5 percent). Wind erosion causing the surface drainage ditches to be filled and blocked with soil resulted in crop damage due to flooding, thus emphasizing the need for wind erosion control measures on smoothed land. No soil movement by water was noted between soybean rows even when rows were 640 feet long on a 0.5 percent grade. A study to evaluate the effectiveness of land forming used singly and in combination with subsurface drainage was installed in Northern Ohio. Initial testing will be undertaken in 1960.

In the Black Canyon Project in Idaho, highly significant increases in water intake rates on slick spot soils have resulted from various treatments of applied gypsum, and mixing of soil profile to depths of 22 to 60 inches compared to untreated areas. Terminal intake rates have increased from 0.01 inches per hour and less on untreated plots to more than 0.6 inches per hour on the gypsum-only treatments to slightly more

than 2 inches per hour on the deep-mixed plots plus gypsum. Although initial intake rates on some treatments were excessive, mixed plots receiving gypsum have continued to decline over the 2-year period and appear to be approaching satisfactory rates. During the summer months, water failed to penetrate nontreated plots more than 1 or 2 inches into the soil, and alfalfa growth was almost nil compared to 9.5 tons of alfalfa per acre produced on deep-mixed plots with added gypsum.

Continued work at Laramie, Wyoming, on assessment of cover effects on infiltration on rangelands indicate that from 60 to 85 percent of variation in intake is accounted for by standing vegetation and mulch on the soil surface. On both sandy and silty soils, standing vegetation has a major influence, but on silty soil effects of mulch on the surface are not of consequence.

At Pinedale, Wyoming, a 4-year program to convert a low producing wet meadow (0.5 tons per acre) into a high producing irrigation system has been highly successful. After breaking the sod initially, repeated seeding to peas and oats with intermittent land leveling during the first 2 or 3 years gave excellent hay yields and opportunity to properly grade irrigation borders for good water control. In the fall of 1957, meadow foxtail and alsike clover were seeded following adequate application of nitrogen and phosphorous. In 1959, a crop of 144 pounds of clean meadow foxtail seed and 3.2 tons of forage were harvested. The hay contained 8.8 percent crude protein. Results demonstrate the potential of converting certain mountain meadows with adequate soil depth into an efficient producing irrigation system.

At Bushland, Texas, intake rates of Pullman silty clay loam, approximately 3 years after plowing under alfalfa, continue to be 50 to 100 percent higher than corresponding continuous sorghum or continuous wheat treatments. Intake rates are generally decreasing on the alfalfa treated plots particularly within the growing season following the preplanting irrigation. Stubble mulch tillage or moldboard plowing have not generally increased intake rate over the 4-year experimental period. However, deep chiseling on alfalfa plots has further increased intake rates. In summary, overall intake rates at the beginning of the experiment were low, ranging from 0.05 to 0.09 inches per hour. After plowing under alfalfa, the intake rate of all plots remained essentially the same during the first year. One year later, a marked three to fourfold increased intake rate was noted on the alfalfa treated plots. This increased intake has persisted for more than 2 years and presently remains about 50 percent greater than continuous grain or continuous sorghum plots.

At Yuma, Arizona, a study was made to determine the effect of the chemical SS-13 on water-holding capacity and intake rate of the Yuma Mesa soils which are very sandy. The only significant result obtained from this study was that infiltration rate was decreased considerably during the time the SS-13 was applied in the water. In the irrigations that followed application of SS-13, there was essentially no difference in intake time between treated and untreated sandy plots.

Plans: This work will be continued at approximately the same level. Where new highly trained engineers are available more effort will be made to relate basic hydraulic factors to water management system design.

Publications: New Water Conservation Research Laboratory for the Arid Southwest. Lloyd E. Myers. Soil Consv. 25(8): 182-184. March 1960.

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Land Forming - A New Water Management Practice. L. F. Hermsmeier and Curtis L. Larson. Farm and Home Sci. 17(1): 8, 9. October 1959.

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Land Forming Shows Promise. J. H. Lillard and Phelps Walker. Extension Service New Developments. June 1959.

Agricultural Drought in Minnesota. F. D. Whisler, C. H. M. Van Bavel, G. R. Blake and E. R. Allred. Minn. Agr. Expt. Sta. Tech. Bul. 235. May 1960.

5. AQUATIC WEEDS AND PHREATOPHYTES CR

Problem: Aquatic weeds greatly reduce the efficiency of irrigation and drainage canals and farm ponds and increase the cost of operation and maintenance. Phreatophytes on ditchbanks and bottomlands waste large quantities of water, interfere with efficient handling of irrigation water, and create flood hazards.

Program: A continuing and long-term research program involving fundamental and applied studies on the control of problem species in cooperation with the Bureau of Reclamation, the Corps of Engineers, and State Agricultural Experiment Stations at 8 locations in 7 states involving about 12 professional man-years annually.

Progress: A survey completed in 1959 showed that losses caused by aquatic and bank weeds in all irrigation systems of the 17 western states totalled nearly $6,000,000 in 1957. About two-thirds of the losses were caused by aquatic weeds and one-third by bank weeds. The total cost of weed control in irrigation systems of the 17 western states was more than $8,000,000, but the losses that would otherwise have occurred were estimated to exceed $15 million.

One seed of sago pondweed planted in the spring in soil under water produced 38 grams of air-dried vegetation and 304 new tubers in one season. One chain of two tubers similarly planted produced 1,040 grams of air-dried vegetation, 5,522 new tubers, 1,375 seeds, and 252 winter buds in one season. The diameter of plants developed within 6 weeks after planting

was 3 feet from the seed and 6 feet from the tuber.

In other life history studies at Huntley, Montana, the average cattail spike was found to contain 222,694 seeds. Observations of cattail and sedge plants grown from seed showed that as many as 11 and 6 new shoots, respectively, can be produced from each seed in one growing season.

A total of 854 new chemicals were evaluated for effectiveness on excised plants of 5 species of submersed aquatic weeds in laboratory tests conducted under contract with the Alabama Agricultural Experiment Station. One hundred thirty-one of these compounds showed average toxicity to the five test species of 91 percent or higher at 5 ppm. Of these, 121 were tested against fish and 17 proved safe on fish at 10 or 5 ppm. These are being evaluated in advanced tests on rooted plants leading to final evaluation of the most promising in large scale field trials.

Thirty-six of 69 chemicals evaluated against 4 species of submersed aquatic weeds in laboratory tests at Denver, Colorado, produced average injury ratings of 80 percent in still water tests at 50 ppm for one or more weeks. Only 3 of these proved effective in flowing water tests at 50 and 100 ppm for 30 minutes.

Acrolein applied at 1 to 3 gallons per cubic foot per second gave outstanding control of sago pondweed and other submersed aquatic weeds in irrigation channels in Arizona, Montana, Washington, and Wyoming. Satisfactory control was obtained 1 to 8 miles, averaging 3.5 miles, down the canal from the point of application.

Xylol, the aquatic herbicide most widely used in the past for controlling submersed aquatic weeds in western irrigation systems, gave satisfactory weed control for an average distance of only 1.9 miles in the same regional test program. Three quaternary ammonium compounds that had given promising results in laboratory trials were considerably less effective than either acrolein or xylol in the regional field evaluation program.

In Arizona cotton irrigated with 25, 50, and 100 ppm of acrolein did not show visible symptoms of injury or significant reductions in yield as compared to checks irrigated with untreated water. In Montana acrolein at 15, 30, and 60 ppm in 3 acre-inches of irrigation water did not reduce the yields of pinto beans, silage corn and sugar beets. In Washington acrolein at 20, 60, and 150 ppm in 2 acre-inches of irrigation water caused slight to severe temporary injury to corn but no significant reduction in yield. The two higher concentrations significantly reduced yields of soybeans.

Growth of water stargrass in different percentages of natural sunlight during 28-day periods was studied in a greenhouse experiment in Arkansas. The percentages of full sunlight utilized were 100, 23, 9.6, 5.8, and 2.8, and the total increase in water stargrass growth was 100, 64, 37, 37, and 5 percent, respectively. The experiment indicated that water stargrass will grow well under greatly reduced light, the compensation point being near 3 percent of natural sunlight.

Complete control of water lettuce, water fern and duckweed was obtained in Florida with 1:1'ethylene-2:2'-dipyridilium dibromide at 3 and 5 lb/A. This compound appears to be the most effective one known for control of water lettuce. This chemical gave complete above water kill of alligatorweed at 1 lb/A active ingredient but regrowth occurred soon after treatment from unaffected submersed stem nodes.

Amitrol-T was more effective on water hyacinth than other herbicides tested in Florida experiments. Nearly complete control was obtained with 2 lb/A.

Amitrol, dalapon, and 2,4-D alone or in combinations of two chemicals have given better control of cattail, Carex, and many bank weeds than have other methods in Montana, Washington, and Wyoming. Two applications per year of 2,4-D at 6 lb/A as an ester in oil-water emulsion has given complete elimination of cattail in one or two years. Amitrol at 8 to 12 lb/A or dalapon at 15 to 20 lb/A applied in late summer has been equally effective on cattail.

Two applications per year of amitrol at 10 lb/A or of 2,4-D at 80 lb/A have eliminated Carex in one or two years. Three applications per year of dalapon at 10 to 20 lb/A have kept Carex under control but have not eliminated it.

Mixtures of dalapon and 2,4-D and of amitrol and 2,4-D have given outstanding control of broadleaved and grass weed mixtures on ditchbanks with relatively low expense.

An experiment on control of salt cedar in Arizona conducted during 1956 to 1959 showed silvex to be more effective than 2,4-D or 2,4,5-T in initial applications and early retreatments. At test rates of 3,4, and 5 lb/A the higher rates of each chemical gave better results early but after three retreatments there usually was little advantage for the higher rates.

Ecological studies in Wyoming at an altitude of 5000 feet since 1956 show that salt cedar has produced an abundance of viable seed each year and new seedling infestations have become established each summer on wet sand and silt bars along streams and around reservoirs. Short growing seasons and winterkill have retarded growth of salt cedar but the species appears sufficiently well adapted to comprise a potentially serious weed pest on irrigation systems and streams in northern states and at high altitudes.

In Wyoming broadcast applications of fenuron pellets at 10, 20, and 40 lb/A active ingredient killed 99 to 100 percent of salt cedar plants averaging 6 feet tall. Basal spray applications of a 50-50 mixtures of butoxyethanol esters of 2,4-D and 2,4,5-T to the lower 15 inches of the trunks of salt cedar plants 3 to 9 feet tall at concentrations of 0.5, 1, and 2 percent in diesel oil killed 70, 88, and 94 percent, respectively, of the salt cedar plants.

Plans: It is expected that research will continue at all of the locations with emphasis on uncompleted experiments and initiation of new experiments on other problems as available resources permit.

Publications: Salt Cedar Control with Chemicals. H. F. Arle. Proc. Western Weed Control Conf. 1959.

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Growth of Heteranthera dubia (Jacq.) MacM. in Various Percentages of Natural Sunlight. R. E. Wilkinson. Weed Society of America Abstracts: 66-67. 1960.

New Developments in Aquatic and Ditchbank Weed Control. R. R. Yeo. Proc. 12th Annual Water Users. Irrigation Conf., Billings, Mont. 1960.

Control of Watercress (Nasturtium officinale R. Br.) with Pre-emergent Application of Granular Herbicides. R. R. Yeo. Western Weed Control Conference Res. Prog. Rpt. 1960.

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6. IRRIGATION WATER SUPPLIES, STORAGE, AND CONVEYANCE SWC

Problem: To control water loss through evaporation and seepage from agricultural water storage structures, canals and ditches, and facilitate storing water underground for later use.

Program: A long-time continuing program involving studies of agricultural water supplies, conveyance and storage, in cooperation with State Agricultural Experiment Stations and the Soil Conservation Service and using about 3 professional Federal man-years annually.

Progress: Three field installations of prefabricated asphalt-coated jute lining have been completed. First in Tremonton, Utah; second, on the Colorado State University Farm at Fort Collins, Colorado; and the third, on the New Mexico State University Farm at University Park, New Mexico. The width of the strips used in these installations was 32 inches; allowing a 2-inch overlap resulted in effective widths of 30 inches. The seams were sealed using a heating technique with heat supplied by a propane torch to soften the asphalt on the top and underside of the joints after which they were pressed together. This prefabricated burlap lining has 15-ounce jute sacking that has been treated with coppernaphthanate. The sacking is then saturated with asphalt and coated with a low penetration asphalt. The material is then dusted to prevent sticking when packaged in rolls for handling and shipping. A soil sterilant is applied to the subgrade before installation, and a clay emulsion is sprayed on the surface for protection against exposure. Tentative plans indicate that this material will be marketed on a limited basis in the Denver area this year. Retail costs have been estimated at less than $1.00 per square yard. Butylon paint would cost about $0.11 per square yard.

One of the most promising treatments for burlap for protection against rotting is cyanoethylation. After 30 weeks of exposure in a soil compost, treated samples still retained 95 percent of the original strength, while untreated material retained only 25 percent in 1 week, and lost all strength in 2 weeks.

Three types of ground covers for collection of percipitation are now under test in Green Canyon, Utah, consisting of black vinyl film, 8-mil thickness; butyl sheeting, 15-mil thickness; and asphalt-coated jute coated with a clay emulsion. All three of the ground covers can be installed for less than $1.00 per square yard. With an assumed life of 10 years, the cost of collecting water in an 8-inch rainfall area will be approximately $2.20 per 1,000 gallons neglecting interest. With

interest of 7 percent, the cost would be about $3.10 per 1,000 gallons. Preliminary laboratory tests at Tempe, Arizona have indicated that sodium soap applied directly to the surface of a sandy soil at an application rate which would cost less than $0.01 per square yard for materials completely stopped infiltration. This material may have application in the contributing areas for stock ponds.

Buried asphalt membranes have generally given better seepage control than thin earth liners. Not only has the variability been less from year to year, but variations in measurements within the year have been much less. After 12 years, these linings are controlling seepage about as effectively as they did when first installed. Plastic film linings in the test reservoirs have continued to give good seepage control. Another recent example of the use of plastic film is for canal linings. The Alberta Department of Water Resources installed a buried polyethlene film lining in about 7 miles of canal on the St. Mary's Irrigation Project last year.

Studies of the physical characteristics of various bentonites at Reno, Nevada, indicated that maximum volumes were reached from 3 to 21 days after wetting. These results indicate that continued swelling of bentonites may have an important role in the sealing process when the bentonite dispersion method of sealing porous irrigation conveyance channels is used.

Studies of butyl rubber have indicated that it will retain its original properties for many years. A ditch lining of exposed butyl showed no deterioration after 10 years of service.

Three small irrigation reservoirs were constructed during September and October 1959, and lined with 8-mil black vinyl pond liners. They are of 1.5, 5, and 9 acre-foot capacities. This is the first installation of this type bid and built by private contractors and indicates the acceptance and practical application of film for lining agricultural water storage reservoirs. Several small reservoirs lined with 8-mil vinyl are under continued observation in the Eastern states. Particular attention is being given to weathering characteristics under varying degrees of soil conservation.

In cooperative recharge tests with the High Plains Underground Conservation District and Dow Chemical Company in the High Plains of Texas, the following results were obtained: When using a Flocculent, Separan AP-30, in a test conducted in April 1959, the amount of silt and clay entering a recharge well was reduced by 49 percent. In this test, the flocculent was added at the intake in the lake, and sediments in the water were allowed to settle in a sump prior to recharging through the irrigation well. A 1-hour pumping cycle followed the recharge period. The combination of the flocculent and pumping cycle resulted in 50 percent less sediments in the well as compared to 7 to 10 percent removed using the 1-hour pumping cycle alone. Tests to reduce sediment loads were conducted by dusting six lakes with the same flocculent using a crop dusting airplane. Sediment measurements indicated that from 43 to 93 percent of the sediments in playa lake water may be removed by flocculation and settling. The percentage reduction in sediment load by flocculation and settling was

generally greater than 50 percent following dusting with the flocculent. Factors which tend to offset the efficiency of the flocculent after the sediment content has been reduced are: High winds which cause mixing; and additions of sediment laden water to the lake in the form of rainfall run-off or irrigation tailwater.

At Bushland, Texas, tests with a field model sand filter and Separan NP-10 succeeded in removing sediments from the lake water, but an accumulation of sediments on the surface of the filter reduced with hydraulic conductivity of the filter considerably. Similar tests with NALCO-600 removed the sediments equally as well and average infiltration rates were more than doubled. When using the NALCO flocculent, the sediments penetrated several inches into the filter instead of accumulating on the surface. Laboratory studies of these two flocculating materials indicated that large flocs formed by Separan flocculents resulted in the accumulation of the surface of the filter. The Separan flocculents also caused a crust to form on the surface of the sand. The crust, having a thickness of 1/4 to 1/2 inch, was the primary limiting layer in the sand filter. Filtering rates obtained with the field model filter during 1- to 2-hour tests varied from about 1 gallon per minute per square foot of filter area to 2.5 gallons per minute. Four model filters were also studied at Bakersfield, California. Preliminary results indicated that a higher permeability is obtained when water is allowed to flow over the sand filter as compared to water pooled over a sand filter.

Plans: This work will be continued at approximately the same level at most of the field locations. At the new Laboratory at Tempe, Arizona, new studies on evaporation, development of low cost, practical and accurate methods of measuring water in farm irrigation systems, reduction of seepage losses and improvement of infiltration rates will be undertaken.

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7. ECONOMICS OF WATER DEVELOPMENT AND USE FE

Problem: Expanding water requirements and increasing competition among uses have resulted in water use and control becoming an increasing national and regional problem. Individual farmers, groups of farmers, and public agencies are affected and need assistance in dealing with economic problems encountered. The work is directed toward increasing effectiveness of water

resource development and use in the interests of agriculture and the economy as a whole.

Program: Activities include research and service to provide basic economic information and develop improved practices for the formulation, evaluation, and selection of water resource development projects. Types of research and investigations include benefit-cost analysis of proposed and installed measures and projects; comparisons of the economic advantages of alternative practices and facilities for water development, conservation, control and use; the value of irrigation water; and the merits of various arrangements for implementing desired programs. A considerable part of the program has been devoted to service research and assistance for operational agencies responsible for formulation and execution of water development programs. The major forms of assistance of this kind include that rendered the Soil Conservation Service in carrying out the Department's watershed protection and flood prevention program; and participation with the Soil Conservation Service and the Forest Service in the conduct of River Basin Surveys undertaken in cooperation with other Federal agencies. Related service activities include the review of water development proposals of other Federal agencies, participation in the preparation of materials and reports on water and related land resources requested by legislative committees and U. S. study and review commissions. The work is carried on in Washington and in many parts of the country, generally in cooperation with State agricultural experiment stations, with some phases cooperative with other Federal and State agencies. It involves about 20 man-years annually.

Progress: Participation was continued in the work of the Evaluation Standards Subcommittee of the Inter-Agency Committee on Water Resources. A report was issued proposing an interim schedule of values for evaluating the recreational aspects of fish and wildlife and work undertaken on developing a report on cost-sharing methods.

Basic data and information on irrigation were assembled and analyzed at Washington and at field offices located at the agricultural colleges in Texas, South Carolina, Mississippi, Nebraska, Nevada, Colorado, Utah, and Missouri.

A study of land and water potentials and future requirements for water was made for the Senate Select Committee on National Water Resources. The study indicated a need for a 10 million-acre increase in irrigated land, the drainage and conversion to cropland of about 30 million acres now in pasture and forest, and the drainage of 30 million acres of land now considered cropland, if we are to meet the agricultural production needs of a population of 329 million in the year 2000. The projected increase in irrigation would require an annual storage and diversion of 200 million acre-feet of water annually as compared to an estimated 150 million acre-feet used in 1960.

A study of irrigation in the High Plains cotton area of Texas indicates that the acreage irrigated in the area increased from 160,000 acres in 1937 to 3.5 million acres in 1958. Water levels declined an average of about 43 feet during that period. Practices used to cope with the lowering

water table include: (1) increasing the hours of pump operation, (2) lowering pumps, (3) installing additional wells, (4) installing closed distribution systems to reduce transportation losses, (5) increasing the proportion of crops irrigated in fall and winter, (6) concentrating available water on cotton, and (7) reducing the acres of cropland irrigated per farm. In general, these practices result in higher investment and operating costs per acre. A bulletin reporting results of the study is nearing publication.

Work continued on an economic appraisal of supplemental irrigation in the Delta area of Mississippi. The 1958 and 1959 crop years were relatively wet and little cotton was irrigated. There was considerable irrigation in 1960 and information was collected on yield increases and costs of irrigation and its tabulation and analysis is now in progress.

In a study of humid area irrigation trends and potentials, corn yield data from experimental plots at the Delta Branch Experiment Station at Stoneville, Mississippi, were related to rainfall data for a 25-year period. Using recently developed methods of drought measurement and computation of probabilities of drought occurrence, the analysis indicated that net returns from irrigating corn would be maximized with an average annual application of 6 inches of irrigation water.

In a study of the use of water for irrigation on Missouri farms, a sample of 65 irrigators in four selected counties were interviewed to obtain costs of installing and operating various types of irrigation systems, the kind and acreage of irrigated crops, and the estimated yield responses. Of the 65 farmers, 46 carried out some irrigation in 1959. Cotton and corn were the major crops irrigated, with smaller acreages of soy beans, strawberries, pasture, and vegetables.

Total investment averaged $7,100 per farm for water, pump and power unit, and distribution system. System capacities ranged from 50 to 510 acres and investment in irrigation equipment averaged $57 per acre.

Forty-nine percent of the farmers irrigating cotton reported an estimated average yield increase of 143 pounds of lint cotton per acre; but fifty-one percent of the cotton irrigators reported no yield increase. Of those irrigating corn, 62.5 percent reported an estimated average yield increase of 36 bushels per acre and 37.5 percent reported no yield increase.

An economic study of the high water table problem on the Newlands Reclamation Project in Nevada, cooperative with the Soil and Water Conservation Research Division, ARS, has been completed and a report is in process. It was found that poor drainage and unregulated water tables are causing decreases in yields and there is a need for water level management. Some alleviation of the problem can be accomplished by better irrigation methods. Although individual farmers cannot afford water level control measures there is a possibility that project-wide control would be economically feasible.

A study of profitable farm adjustments to limited supplies of irrigation water in the Upper Colorado River Basin is being conducted at two locations, one in Colorado and one in Utah.

A study of intrafarm allocation of water in the Gunnison, Colorado, area has been completed and a report is being prepared for publication. The study attempted to determine the marginal values of increments of irrigation water when associated with changes in management. Results indicated that these marginal values are fairly high, possibly $20 per acre-foot, under the study conditions. It was found that farmers generally do not vary their farm operations in response to predicted water supplies. When water is short, they put available supplies first on high-valued cash crops, such as sugar beets and corn; and any residual is applied to pasture and forage crops.

A study of values of water for irrigation and competing uses in the Upper Colorado River Basin has been concerned with the rental market for irrigation water within the area blanketed by the Northern Colorado Water Conservancy District. A study of the records of 5 major irrigation companies in the area showed that 645 rental transactions occurred in 1959 transferring over 16,000 acre-feet of water. Approximately 87 percent of these transfers occurred during the months of July, August, and September. Ninety-three percent of the transactions involved the transfer of less than 60 acre-feet of water. Prices ranged from a low of $2.50 per acre-foot for early season water to $8.00 per acre-foot late in the season. Prices are reputed to go as high as $30 per acre-foot under extremely short supply conditions.

The Northern Colorado Conservancy District, which distributes Colorado-Big Thompson project water diverted from the western slope, reported 376 transactions involving approximately 74,000 acre-feet of water. These transactions generally represented larger quantities of water. About 28 percent involved quantities of more than 60 acre-feet.

Work is underway on economic appraisal of water use in agriculture in relation to nonagricultural uses and water supplies. A survey of national source materials on present and projected water uses and supplies was completed and a preliminary draft is in process. Information from this survey was used in the paper: "Water for Agriculture and Competing Uses in the Great Plains," given at the 1960 annual conference of the Great Plains Agricultural Council. Data from the survey, combined with a review of payments made for water in irrigation, domestic, and industrial uses were reported in: "Price and Assessment Guides to Western Water Allocation," given at the 1960 annual meetings of the American Farm Economics Association.

Activities under a study of the economics of watershed management have included: (1) continuation of methodological economic research in the Spring Valley Creek watershed in western Iowa, and (2) a survey of all soil and water conservation research in the U. S. bearing on watershed management economics. Analysis of data accumulated for the Spring Valley watershed project indicates that such interfarm damage problems as gullying

and flooding are not as acute as preliminary surveys had indicated. The national survey of research indicates that about 454 publicly-financed studies concern the economic aspects of soil and water conservation in general. About 127 of these are oriented to watershed planning. Watershed studies involving only the collection of physical data useful in economic evaluations total 89. Specialized economic research on watersheds is involved in 17 studies, while 21 additional studies are jointly physical and economic.

A study of the economics of watershed protection programs in Oklahoma compares use of flood-plain land in a watershed having flood-detention structures with flood-plain use in two watersheds without such structures. A budget analysis indicates that alfalfa is the most profitable crop where flooding is infrequent and native pasture the most profitable under frequent flooding. Observed land use in the three watersheds tends to bear this out. In the watershed having structures, 36 percent of the flood-plain in sample farms was in alfalfa, whereas less than 10 percent of similarly located land was in alfalfa in the unprotected watersheds.

A study of the characteristics, use, and occupancy of rural flood plains is being conducted by the Department of Geography, University of Chicago, under contract. An exploratory investigation has resulted in the tentative selection of five major factors affecting rural flood-plain use: (1) frequency or probability of floods, (2) seasonality of floods, (3) slope of the channel and of the flood plain to the channel, (4) width of flood plain, and (5) size of the drainage area.

Research on the economics of land-forming for water management is underway in cooperation with the Iowa Agricultural Experiment Station. A small number of farmers and contractors have been interviewed in North Central and Central Iowa on their experience with "cut and fill" terraces. This practice involves the grading of fields to a constant slope and the installation of parallel terraces. Farmers reported costs ranging from 8¢ to 22¢ per linear foot as compared with about 5¢ for standard terraces.

Work was continued on the joint ARS-SCS program to evaluate effects of works of improvement installed under the Department's pilot small watershed program in both physical and economic terms. Seven watershed projects in six states are being evaluated. Annual evaluation reports were made for Six Mile Creek, Arkansas, Upper Rio Hondo, New Mexico, and Kiowa Creek, Colorado. In Six Mile Creek, the estimated value of actual benefits in 1959 from prevention of flood and sediment damage was $53,800. The average annual benefit for the last 5 years is estimated to be $41,800. These experienced benefits tend to confirm the original estimates made when the watershed project was planned. Farmers on whose land floodwater-retarding structures were built are receiving more income from these areas than was expected when the project was planned. Water from the sediment pools of two floodwater-retarding structures is being used to supplement existing supplies of municipal water. One other pool is used as a source of supply for industrial water. Three additional lakes have been leased to clubs on an annual basis for recreational uses. Industrial water is being used by two new manufacturing plants which employ

600 persons. Monetary returns to the owners of the pools for such uses totaled $1,500 in 1959. Continued studies of Kiowa Creek indicate an increase in the conversion of bottom land to higher intensity use due to the reduction in flood and sediment hazards. Preliminary appraisals in Plum Creek, Kentucky, reveal a significant benefit from prevention of flood damage during the June 1960 flood.

An inventory of basic data from P. L. 566 watershed project work plans was made available to the Soil Conservation Service for assistance in the economic evaluation of planned programs. This tabulation was based on 264 approved projects as of July 1, 1960, which included more than 15.6 million acres and sustained an average annual damage of 20.5 million dollars. The average annual installation cost was equal to $22.48 per acre, of which 65 percent is allocated to structures and 35 percent to land-treatment measures. Of the estimated 18.5 million dollar annual benefits, about 92 percent is from flood prevention and the remainder is attributed to agricultural water management and uses of water for municipalities, fish and wildlife, and other nonagricultural purposes.

Special investigations were undertaken to develop flood damage factors to growing crops in the Southeast and in the Great Plains with the objective of preparing schedules of damages that can be applied in watershed planning with only minor local modifications. Approximately 200 records of damage experience have been obtained from farmers in Kansas.

A report of a special investigation of fish, wildlife, and recreation benefits of commercially operated reservoirs in three sites indicated the feasibility of evaluation procedures for estimating the volume of recreational use in relation to the density of population in the surrounding area.

A special study in Utah to design a method of evaluating irrigation benefits was completed. This study disclosed a practical procedure for estimating irrigation benefits from increased water supply based on the relationship of crop yields to volume of water applied.

River Basin Investigations were conducted in six river basin areas during the year. Survey activities were completed in two basins; studies were initiated in three additional areas; plans were developed for three additional investigations; and consulting services were provided for two reconnaissance surveys conducted by the Soil Conservation Service. This activity involves developing agricultural information and appraisals essential for the formulation and economic evaluation of resource development projects and programs of other public agencies and is cooperative with the Soil Conservation Service and the Forest Service. The agricultural base for development plans is by technicians in the fields of economics, engineering, soils, agronomy and forestry.

Surveys under way in the Upper Colorado River Basin are designed to evaluate direct agricultural benefits of "participating irrigation projects" authorized by the Colorado River Storage Act. Department of Agriculture

studies are concerned with the suitability of project lands for irrigation farming, land use and crop production likely to result, costs of developing project lands for irrigation use, types and sizes of farms most desirable and most likely to result from project development, increases in farm income that may be anticipated from new or additional development of irrigated land, and other agricultural factors necessary for a comprehensive evaluation of the proposed projects. Progress includes: (1) completion of field surveys in the Lyman and LaBarge project areas in Wyoming; (2) designing and carrying out a field survey for the Duchesne project unit in Central Utah; (3) summarization and analysis of economic data for the Emery County project, Utah; and (4) partial analysis of data for the Duchesne, West Jordan, and Heber-Francis project units in Utah, and the Lyman and LaBarge projects in Wyoming.

Progress on the cooperative survey of the Potomac River Basin included the preparation of four technical reports during the year: (1) "An Analysis of Recent Changes and Probable Future Trends in the Agricultural Economy of the Potomac River Basin;" (2) "Past, Present and Future Land Use in the Potomac River Basin;" (3) "Future Irrigation Development in the Potomac River Basin;" and (4) "Present and Projected Estimates of Rural Water Requirements Excluding Irrigation in the Potomac River Basin." Work is still underway on flood damage and land enhancement analysis, dam site impact studies, and basinwide project formulation in conjunction with the Corps of Engineers. Completed work indicates that rural water requirements, excluding irrigation, may increase as much as 500 percent; that land in farms has declined from 7 million acres in 1900 to about 5 million in 1958 and that additional declines to 4.5 million by 1980, and to less than 4 million by 2010 may be expected; that the number of farms had declined from a peak of 65,400 in 1910 to about 40,800 in 1958, and that further declines to less than 31,000 in 1985 and to about 26,000 in 2010 are likely; that about 25,000 acres of irrigation may develop in 1985 and that an additional 15,000 acres may be irrigated by 2010, and that annual losses from agricultural drought amount to $12 million and that such losses for drought conditions similar to 1957 would amount to about $30 million.

In the Sevier, Humboldt, and Upper Willamette River Basins in Utah, Nevada, and Oregon, respectively, the survey objective is to develop comprehensive and coordinated plans for development of land and water resources. FE is responsible for the economic aspects of the survey, with particular emphasis on phases relating to agricultural water use. A report on the present agricultural economy of the Deschutes Basin was prepared.

Activities in an eight-basin area in Texas are being carried out under a cooperative agreement with the United States Study Commission, Texas River Basins. The major assignment is to evaluate alternative potential means of agricultural development and relative costs, and to relate the indicated potential to projected requirements for agricultural products. Agencies cooperating in the survey are the Texas Agricultural Experiment Station, the Soil Conservation Service, and the Bureau of Reclamation. The study consists of five major parts: (1) development of national projections of agricultural product requirements and appraisal of the type and quantity of agricultural products that might logically originate in

the study area; (2) an inventory and appraisal of lands available for agricultural production and analysis of current crop acreages and yields; (3) analysis of the effects of soil and water conservation practices, increase in fertilizer usage, and the application of improved technology on crop yields; (4) an evaluation of future acreage requirements for agricultural production without resource development and major land use shifts; and (5) an appraisal of potential resource development and land-use shifts, their cost, and contribution toward meeting projected requirements.

Activities in an eight-basin area in southeastern United States (Georgia, Florida, South Carolina, and Alabama) are being initiated at the request of the United States Study Commission, Southeast River Basins. Investigational activities are carried out in cooperation with the Soil Conservation Service, Forest Service, and other State and Federal agencies. Successful completion of the investigational program will facilitate the establishment of a comprehensive plan for land and water resource development. Studies are concerned with the development of agricultural and land-use projections and needs; appraisal of agricultural drought losses and benefits from potential irrigation development; development of materials on agricultural losses from flooding and potential agricultural benefits from flood protection and alternative opportunities and comparative costs of increased agricultural production.

Investigations being initiated in the Tombigbee River Basin are devoted to: (1) development of information on national production requirements and relation of them to the study areas; (2) compilation of economic data and development of economic procedures for use in the survey; (3) development of price and cost data required in the survey; and (4) participation with the Soil Conservation Service in the development of projections of land use and agricultural production for attainable levels of potential resource development and for alternative systems of water disposal and control.

Plans: Continuation of current research studies on water use in agriculture, irrigation in selected States, water management economics, including extension of the drought probabilities type of analysis to the evaluation of irrigation feasibility in selected river basins, preparation of reports on operation of the water rental market in Northeast Colorado, effect of flood prevention projects on agricultural use of flood plains, and relation of soil erosion to watershed development programs; expansion of studies on land forming to include more areas; and initiation of a cooperative study with the University of California for an economic appraisal of selected water conveyance systems in that State. Continuation of joint ARS-SCS watershed activities, including preparation of final evaluation reports on selected watersheds; expansion of studies to determine the on-site uses of water stored in flood-water retarding structures; intensification of flood damage studies in southeastern States; and initiation of a study to evaluate the impacts of installed watershed protection projects in the Washita River Watershed. Continuation of the basin surveys underway and probable initiation of new joint surveys in the Gunnison Basin in Western Colorado, the Susquehanna River Basin in New York, and the Lower Arkansas River Basin in Oklahoma and Arkansas.

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IV. BASIC SOIL PROBLEMS

1. MINERAL NUTRITION OF PLANTS SWC

Problem: To understand mineral nutrition of plants, particularly the passage of nutrient elements into roots and the functioning of some nutrient elements in plants.

Program: A long-term program in basic research carried on in the Mineral Nutrition Laboratory for pioneering research at Beltsville, Maryland, involves studying the processes by which plants take up nutrients, how the nutrients function in plants, and how mineral nutrition is related to the environment of the plant and the complex process of growth. The purpose is to develop a better understanding of life processes in plants, and especially the role of mineral nutrients in these life processes. Findings of the Laboratory provide a scientific basis for other workers to use in attacking the practical problems of soil fertility and crop production. Continuing long-term research to clarify the mechanisms by which salinity affects plant growth and yields, and to provide information on the properties of plants primarily associated with tolerance to salinity is carried on at the U. S. Salinity Laboratory, Riverside, California. Other basic research on mineral nutrition of plants is carried on at Beltsville, Maryland, State College, Pennsylvania, Fort Collins, Colorado, and Prosser, Washington, mostly in cooperation with State experiment stations. The work involves about 15 professional Federal man-years annually.

Progress: Accumulation of salts is necessary for all forms of life. To understand the controls for this process in plants is an objective of the Mineral Nutrition Laboratory. While primarily concerned with seed plants, we are aware of progress toward understanding of salt balance in other forms of life -- stomach mucosa for acid production and the maintenance of sodium and potassium ion levels in red blood cells, as examples.

Salt accumulation in seed plants depends upon oxygen for respiration. The results of experiments on phosphate uptake by barley indicate that accumulation is closely coupled with energy yielding steps of oxidation of organic materials within the roots. The conclusions presented in the 1959 report were based on the effects of respiratory inhibiting substances such as reductants and barbituates on phosphate uptake by barley plants. Although inhibiting substances are selected for their specific effects, they generally have other effects or points of action which lead to some doubts about the meaning of their actions. This ambiguity is partially met by analysis of the inhibitory effect of a multiplicity of substances.

Another approach that is being developed is measurement of phosphate uptake by respiratory particles separated from roots. These particles, mitochondria, oxidize some of the same organic materials used by roots and utilize a part of the released energy to produce organic phosphate compounds, chief among which is adenosine triphosphate (ATP). The ATP serves as a sort of "currency" to transfer energy through exchange of phosphate from the mitochondria to energy requiring reactions such as

thos preparatory to utilization of sugar. The question pertinent to salt accumulation is the extent to which the isolated respiratory particles parallel the behavior of roots in phosphate uptake.

A third approach depends upon examining salt uptake by yeast which takes place not only in the presence of air as required by roots but also during fermentation. Phosphate accumulation by yeast requires a sugar supply in the growth medium. In the presence of air it closely resembles phosphate uptake by barley roots in rates, parameters, and in response to inhibitors.

Rates of phosphate uptake by yeast are enhanced during fermentation. This increase is accomplished by an increase in the number of entry sites. Actions of inhibitors are closely similar in the presence and absence of air even though the respiratory system is inoperative during fermentation. The phosphate uptake again appears to depend upon ATP formation coupled with an oxidative reaction even though oxygen is absent.

These approaches depend upon following the "kinetics" or actual transport of a salt or ion entering a plant. They resemble the analysis of any transport system that must be examined while it is functioning. Some knowledge is to be gained, however, from a dead system, particularly for salt uptake, to find where the salt is located in the root after periods of uptake as short as a few seconds. The problem here is to obtain thin sections of radioactive root tissue with as little modification as possible and then to make radioautographs of this tissue.

Two major factors affecting chlorosis of plants are involved in the entry of iron from the soil into plant roots. One is that reduction of iron is probably effected at the root surface. Iron salts, however, are very insoluble in the soil and they can only be maintained at an adequate level for plant nutrition by being held in solution as complexes or chelates. The roots not only have a capacity to reduce iron but also form chelates which facilitate the entry of iron into the plant.

Roots of various plants differ in their reductive capacities and in their abilities to chelate iron. Moreover, after iron enters the plant it can be inactivated by reaction with phosphate and possibly other plant constituents. The degree to which plants differ in these factors and the extent to which phosphate and iron are supplied by the soil determine, in part, the development of chlorosis or yellowing.

The iron supply of the soil depends upon the properties of the soil solution, particularly on the acidity and the presence of carbonate. Many soils containing great amounts of iron, evidenced by their red colors and iron contents, require careful management to supply amounts of the nutrient element adequate for healthy plant growth.

As previously reported, phytochrome, the active principle of photoperiodic control of flowering and many other responses of plant growth to light, was separated from corn seedlings on June 19, 1959. This was the attainment of a major objective inherent in the discovery of photoperiodism forty years ago by W. W. Garner and H. A. Allard.

Phytochrome is a colored protein that controls growth through change of molecular form by light. In darkness phytochrome reverts to an inactive form. The rate of the reversion is a controlling factor in determining the flowering and growth of plants. The change in molecular form induced by light is required for the germination of many seeds and stops the lengthening of seedlings as they emerge from the ground.

Phytochrome is present in all seed plants. Its concentration, however, is never greater than about one part in a million of the total weight. The best source for its isolation is six-day old corn seedlings. The purification of phytochrome is in progress and, if successful, will be followed by a search for its enzymatic action involved in control of plant growth.

The installation of a Baird-Atomic direct-reading spectrograph was completed in March and has been in successful operation since that time. The principal use of this instrument is for the rapid analyses of plant tissue obtained during the course of mineral nutrition studies. In this connection, a hypothesis has been stated that element-variability patterns in plant tissue composition define optimum growth-concentration ranges for nutrient elements. Experiments are currently under way to further evaluate this hypothesis, with particular emphasis on trace element requirements.

The phosphorus in the soil solution must be renewed many times a day to supply the needs of the plant. Partial renewal takes place by dissolution of phosphorus from the surface of soil particles adjacent to the root. The remainder of the renewal occurs by movement of phosphorus over relatively long distances. Greenhouse experiments indicated that phosphorus diffusion in soils was too slow to account for the major amount of renewal. Soil water movement can account for this major movement and essentially has the effect of sampling a larger soil volume for replenishment of the soil solution.

Many soils are too low in sulfur for satisfactory plant growth. Available soil sulfur was determined by the 'A' value technique by using radioactive sulfur as the tracer for added sulfur. The 'A' values were highly correlated with yield response to added sulfur, sulfur percentage in cotton tissue, and total uptake of sulfur. 'A' values were not increased by liming although improved plant growth often resulted in a greater removal of sulfur from the soil. The results obtained in this study served as a basis for developing a laboratory method which measures available sulfur in soils.

The mechanism of movement of ions from the soil solution to the top of the plant determines the effectiveness of soil solution concentrations of nutrient ions and the effect of environmental factors on ion uptake. By kinetic analysis of tracer experiments with rubidium, this mechanism was partially resolved. To reach the top of the plant rubidium and therefore potassium and probably other cations must go through at least one active metabolic process. This controls the concentrations of ion reaching the xylem. The ion then moves up in the transpiration stream

and the rate of this movement determines the amount reaching the top over a short time period. The concentration of the ion in the transpiration stream appears to be in equilibrium with the prior active process in the root.

The "carrier" hypothesis for the mechanism of ion uptake suggests at least 3 factors affect the rate of ion uptake; namely, the concentration of the carrier M, the concentration of ion and the rate of dissociation or transformation of the carrier complex MP. The influence of soil moisture on ion uptake appears to be associated with carrier M. The effective concentration of M may be expected to change with root elongation and the aging process of cells; these, in turn, are influenced by soil moisture tension. Further, an interaction of soil moisture by temperature was found, suggesting that the metabolic formation of carrier M is also related to soil moisture stress. Since the concentration of soil phosphorus influences the concentration of MP and temperature influences the dissociation of MP, a significant interaction of phosphorus by temperature was predicted and observed. The linear relationship between phosphorus uptake and soil solution concentration found suggests a separation or space barrier between ions in the soil solution and carrier M.

Observations at University Park, Pennsylvania, show poor growth of roots in acid subsoils can be corrected by raising the pH of the subsoil. Soil solution extracts of these subsoils indicate that in addition to a low pH, the soil solution is relatively high in both manganese and aluminum. Tests with soil solutions extracted from an Allenwood subsoil indicate that a toxic amount of aluminum is primarily responsible for the poor growth. Both hydrogen ion competition for cation uptake and a toxic amount of manganese are probably also contributory causes. When plant roots grown in soils are permitted free entry to solution cultures, no entry takes place if the aluminum concentration is 10 parts per million. Aluminum toxicity is characterized by poor root proliferation and increased thickening of the roots.

At the regional phosphate laboratory in Fort Collins, Colorado, studies show that the properties of pure, crystalline calcium phosphate provide useful guideposts to help evaluate the nature of reaction products formed between fertilizer phosphorus and soil. The behavior of the pure compounds in the presence of calcium carbonate and various soluble salts was determined by methods applicable to calcareous soils.

Plans: A major objective of the Mineral Nutrition Laboratory is to understand the way in which nutrients enter plants. While the progress with phosphate is encouraging, real progress depends upon more complete understanding of potassium uptake. A sensitive spectrometer capable of measuring changes in the oxidation and reduction of iron compounds (cytochromes) in roots is being constructed.

Another objective at this time is to find the membrane system in the root that limits salt uptake. To this end, microscopic and radioautographic techniques are being applied to sectional roots.

In our work on iron chlorosis, an understanding of the participating function of chelating agents in ion absorption and the mechanism whereby Fe is released to the root from a metal chelate remain as challenges.

At the Salinity Laboratory particular emphasis will be given to exploring the significance of the salinity effect on nucleic acid metabolism. Nucleic acids not only transmit heritable traits from generation to generation but also control the activities and response of organisms. The finding that salinity can affect the master-control mechanism of the plant can, therefore, represent the start for far-reaching and highly rewarding research.

The research reported at the other locations will be continued and approximately at the same level.

Publications: Photocontrol of Plant Development by the Simultaneous Excitations of two Interconvertible Pigments. II. Theory and Control of Anthocyanin Synthesis. S. B. Hendricks, and H. A. Borthwick. Botan. Gaz. 120: 187-193. June 1959.

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Photocontrol of Plant Development by the Simultaneous Excitations of two Interconvertible Pigments. III. Control of Seed Germination and Axis Elongation. S. B. Hendricks, E. H. Toole, V. K. Toole, and H. A. Borthwick. Botan. Gaz. 121: 1-8. Sept. 1959.

The Bicarbonate Ion as an Indirect Cause of Iron Chlorosis. O. R. Lunt, J. C. Brown, R. S. Holmes, and L. O. Tiffin. Soil Sci. 88(5): 260-266. Nov. 1959.

Detection, Assay, and Preliminary Purification of the Pigment Controlling Photoresponsive Development of Plants. W. L. Butler, K. H. Norris, H. W. Siegelman, and S. B. Hendricks. Proc. Nat. Acad. Sci. 45 (12): 1703-1708. Dec. 1959.

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Products of Orthophosphate Absorption by Barley Roots. P. C. Jackson and C. E. Hagen. Plant Physiol. 35 (3): 326-332. May 1960.

Chelating Agent and Plant Nutrient Interactions Affecting the Iron Nutrition of Soybeans. L. O. Tiffin, J. C. Brown, and R. S. Holmes. Soil Sci. Soc. Amer. Proc. 24(2): 120-123. March-April 1960.

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Radioisotopes and Fertilizers. Maurice Fried and Raymond E. Shapiro. The Grace Log 34(5): 6-8. 1959.

A Kinetic Analysis of Phosphate Absorption by Excised Roots of Millet, Barley, and Alfalfa. J. C. Noggle and Maurice Fried. Soil Sci. Soc. Amer. Proc. 24(1): 33-35. January-February 1960.

Evidence for and Some Implications of a Variation-Control Mechanism in Plant Composition. Alston W. Specht. Soil Sci. 89(2): 83-91. Feb. 1960.

The Solubility of Calcium Carbonate in Calcareous Soils. Sterling R. Olsen and F. S. Watanabe. Soil Sci. 88(3): 123-129. Sept. 1959.

Behavior of P^{32} in Tracer Studies. Sterling R. Olsen and Frank S. Watanabe. Soil Sci. 88(5): 256-259. Nov. 1959.

2. PHYSICS OF EVAPORATION AND TRANSPIRATION SWC

Problem: To develop our understanding of the interrelationships of soils, plants, and climate, and to learn more about the physics of evaporation.

Program: A continuing program devoted to study of how moisture supply and demand controls moisture utilization, involving soil physics, soil chemistry, micrometeorology, and plant physiology principles. Methods of modifying heat budgets, eddy diffusion and factors affecting them are studied. Emphasis is placed on methods of control of soil physical factors that determine moisture intake, retention and transmission characteristics. The work is carried on in 12 states in cooperation with State agricultural experiment stations, and involves about 10 professional man-years annually.

Progress: In New York, heat budget studies in 1959 showed that about 80 percent of the solar energy coming into a corn field was available during the major part of the day for photosynthesis, evaporation, and for heating the environment. Energy losses by reflection and back radiation were found to vary with time of day and with completeness of stand of crop. Methods for establishment of more complete crop cover in order to more effectively utilize solar energy are under investigation.

The influence of crop geometry on the exchange of heat, water vapor, and carbon dioxide between a corn field and the atmosphere, was evaluated in New York. As crop height increased, exchange rate was increased. The effective height of the crop decreased as wind velocity increased, but

movement of non-rigid corn plants in the wind more than offset the effects of reduced height. When corn rows were laid out perpendicular to the direction of the prevailing wind, wind turbulence was increased and exchange rate was increased. These studies of crop geometry open up the possibility of developing a more positive means of conserving moisture during rainfall deficient periods, of more effective dissipation of heat, or of providing larger supplies of carbon dioxide to the crop wherever environmental conditions cause them to limit crop production.

During the past several years, the loss of water by evapotranspiration in humid regions has been equally divided between evaporation and transpiration. In 1959, a project was initiated in Georgia to investigate plant transpiration and to determine the feasibility of controlling transpiration. A growth chamber has been developed in which energy gradients causing evaporation from leaf surfaces can be reproducibly controlled. The energy levels, which extend from zero up to one calory per square centimeter per minute, are provided by incandescent photo flood lamps. Special provisions have been made for dissipation of the heat produced at the highest energy level.

As one means toward moisture conservation, control of evaporation from leaf surfaces is under investigation. Whereas root morphology is important in water absorption, it is assumed that transpiration suppression might best be controlled through chemical coatings on the leaves. Materials are being screened which are more permeable to carbon dioxide and oxygen than to water, for transpiration suppression must be effected without reduction in photosynthesis and respiration. Promising materials will be tested under greenhouse and field conditions.

Warm, windy weather prevailed during the early part of the growing season at Morris, Minnesota, in 1959. These climatic conditions dried out the surface soil. Under these droughty conditions, a high corn population reduced solar energy for evaporation and increased synthesis of tissue. High plant population depleted soil moisture considerably by the time tasseling occurred and, as a result, grain yields were reduced. Under droughty conditions, a reduced stand density will result in increased grain yield.

Significant observations relating evapotranspiration to climatic variability have been made on alfalfa in the Santa Ynez River Valley. Evapotranspiration for the period June 1 to September 30, 1959, was 19.00, 20.83, and 34.21 inches at distances from the ocean of 6, 11 and 28 miles respectively. Within this distance, climate changes from a coastal, humid condition to an almost arid condition. Neither single climatological factors nor U. S. Weather Bureau pan evaporation had as steep a gradient change with distance from the ocean as did evapotranspiration. The climate-evapotranspiration phenomena were similar to those observed with sugar beets and beans in 1957 and 1958.

Factors controlling the movement of water, nutrients, and oxygen through soil to the surfaces of plant roots received major attention in Illinois.

There was considerable evidence to indicate that biological factors as well as physical factors influenced such movement. Increased temperature, increased ion concentration, and increased moisture content caused an increase in ion transfer rate, but uptake of ions by roots and the accompanying concentration gradients that resulted had to be taken into consideration to explain the observed movement rate.

When soil temperature was raised from 15.5° C. up to 30° C., increased flow rates resulted from lowered viscosity of water. Increased metabolic activity also occurred at the higher temperatures which resulted in faster uptake of ions and steeper concentration gradients toward the roots. In like manner, as soil moisture content was increased and soil moisture tension was reduced, the increased growth rate of the plant at the more favorable moisture regime resulted in gradients toward the root.

Recent strengthening of research of basic factors involved in moisture conservation resulted in considerable progress during 1959. At Manhattan, Kansas, attempts to assess the complete heat balance in growing sorghum indicated that approximately 55 percent of the net radiation is absorbed by the crop and 45 percent reaches the soil surface. That reaching the soil surface is available for evaporation of water and heating of the soil. Measurements in this relatively wet year indicated that only about 15 percent of the soil moisture lost was consumed by evaporation; therefore, somewhere near 30 percent of the total net radiation was consumed in heating of the soil.

In addition to assessment of climatic factors, progress was made in analysis and interpretation of influences of climatic factors on moisture conservation. At Bushland, Texas, analysis of long-time records at 25 Great Plains locations indicated a storage of 2 inches of water or approximately 30 percent of precipitation during the fallow interval between annual crops of wheat. In summer-fallow systems, about 4 inches of water was stored on the average or considerably less than 20 percent of the precipitation during the period. Storage efficiency was considerably better in northern areas than in the southern Plains.

In other studies at Bushland, intensive measurements of net radiation, temperature, wind and evapotranspiration over differentially fertilized sorghum indicated no difference in evapotranspiration between 0 and 240 pounds nitrogen rates. For the period July 31 through October 8, evapotranspiration exceeded values computed from climatic measurements by about 16 percent. For certain portions of this time interval, actual evapotranspiration ran as high as 50 percent above the theoretical value. During early stages of sorghum growth, actual evapotranspiration was approximately 0.6 the theoretical value. These data indicate the significance of advected energy in indirect assessment of evapotranspiration in dry areas.

Nine plastic-lined lysimeters, 10-foot square and 7-foot deep, were installed near Winnemucca, Nevada, to determine the evapotranspiration of native meadow vegetation under controlled water table conditions. Black vinyl plastic film, 30-foot square and 20- mils thick was used. Stands

of sedges, bluestem, and saltgrass are being established. The first data will be obtained in 1961. Three additional tanks will be installed near the meadow tanks in which willows or wild roses will be planted. The Geological Survey has installed two lysimeters adjacent to this area for similar studies using greasewood, a phreatophyte common in the area. A cooperative weather station will be used to obtain climatic data for these studies. The combined results of the studies will be used to determine the disposition of water supplies in the Humboldt River Basin.

Lysimeter studies at Reno, Nevada, with alfalfa, a phreatophyte, have shown that evapotranspiration increases as depth to water table decreases.

Studies were continued on the utilization of plastic for evaporation control in crops. At North Platte, Nebraska, complete plastic cover increased grain yield of sorghum 17 bushels per acre and doubled water-use efficiency from approximately 5 to 10 bushels per acre per inch of water consumed. Water use on completely covered plots ranged from 9 to 10.8 inches compared to 16 to 18 inches on noncovered or partially covered treatments. Similar water use and a yield increase of 26 bushels per acre was obtained at Manhattan, Kansas, on plastic covered versus bare plots. At Big Spring, Texas, water use was 12.3 inches on covered cotton plots compared to 23 inches where evaporation was not controlled. Water-use efficiency was 76 pounds per acre of lint cotton per inch of water used on covered plots and 40 pounds per inch on bare plots. Highest water-use efficiency was obtained on covered-nonirrigated plots where 4.5 inches of water produced 526 pounds of lint or 117 pounds of lint per acre per inch of water consumed. Concentration of precipitation and evaporation reduction by covering of ridges did not alter total water use but improved yields approximately 20 percent, thereby increasing water-use efficiency materially.

Water-use efficiency at Temple, Texas, was increased approximately 50 percent by similar partial evaporation control procedures. At Akron, Colorado, similar data indicated that evaporation accounted for approximately 60 percent of total evapotranspiration in sorghum where moisture was limiting and from 40 to 50 percent where higher levels of stored moisture exist at seeding time. Partial evaporation control and water concentration greatly increased yields and water-use efficiency at this location. The data indicate that approximately 0.3 tons per acre of total dry matter per inch of water consumed is obtained irrespective of the yield level.

Plans: This program has been developing for the past several years as special equipment and facilities were acquired. It will now continue at about the same level as these facilities are put into use.

Publications: Some Effects of Elevated Atmospheric Pressures on Growth of Wheat Plants. Herbert R. Gardner and Howard M. Taylor. Agron. Jour. 52(1): 23-25. Jan. 1960.

Water and Ion Movement in Thin Films as Influenced by the Electrostatic Charge and the Diffuse Layer of Cations Associated with Clay Mineral Surfaces. W. D. Kemper. Soil Sci. Soc. Amer. Proc. 24(1): 10-16. Jan-Feb. 1960.

Estimation of Osmotic Stress in Soil Water from the Electrical Resistance of Finely Porous Ceramic Units. W. D. Kemper. Soil Sci. 87(6): 345-349. June 1959.

Cotton Response to Variations in Moisture Studies. R. R. Bruce. Miss. Farm Res. 22(5): 1959.

Orientation Corn Planting Saves Moisture. D. B. Peters and J. T. Wooley. Crops and Soils Vol. 11(8): 22. 1959.

Sheet Plastic Ground Covers and What They Do. C. S. Slater, R. V. D. Broach. Crops and Soils Vol. 12(6): 12-13. March 1960.

3. SOIL STRUCTURE AND TILTH SWC

Problem: Methods for characterizing soil structure and tilth and a better understanding of its significance in the soil-water-plant relationships are needed in connection with its control.

Program: A continuing program to delineate factors which contribute to soil structure and gain a basic understanding of the nature of the forces involved in holding soil particles together in a stable condition, carried on at Beltsville, Maryland, Pomona, California, Ft. Collins, Colorado, Bushland, Texas, and Lincoln, Nebraska, largely in cooperation with State agricultural experiment stations, and involving about 3 professional Federal man-years annually.

Progress: Further significant progress in understanding physical and chemical factors influencing soil structure in arid and semiarid regions have been made at Fort Collins, Colorado. Aggregate stability as measured by wet sieving with modified vacuum wetting procedure has been correlated with clay content, organic matter content, nitrogen content, free iron and aluminum oxides, and exchangeable sodium percentage. A regression analysis of aggregate stability as a function of percent clay and percent organic matter gave the equation: Percent aggregate stability = 29+ 13.8 (% O.M.) + 0.72 (% clay) + 8 (% Fe_2O_3) + 5 (% Al_2O_3). The real significance of these data stems from the fact that progress is being made in describing and predicting soil structure stability in terms of properties capable of numerical expression.

The adequacy of the supply of oxygen, ions, or water at root surfaces is determined by the demands of the plants. Oxygen demands of root tissues and capacity of the environment to supply those demands were evaluated in Illinois. As temperature was increased, respiration rate of root cells was increased and oxygen demand was increased. It was assumed that oxygen could probably move through the external tissue of roots and that the latter might limit aeration. Evaluation of rates of diffusion of gases through potato tuber tissue indicated that adequate supplies of oxygen to meet respiration demands could only be supplied to the external 2 - 3 mm of tissue. These data suggest that aeration would be more critical with thick rooted plants than thin rooted plants unless the root surface

failed to represent the true exterior of the root. Of several peanut species studied in Illinois, 15 to 20 percent of the root volume was freely permeable to ions and water indicating that the root interface was, in some cases, inside the root and not always at the visible root surface.

In New York, the effects of soil texture and soil moisture tension on the rate of diffusion of oxygen through soil were evaluated. Major emphasis was on movement through the liquid phase which is indicative of aeration conditions. Apparently moisture content on a volume basis exerted a dominating influence on oxygen diffusion rates regardless of texture or soil moisture tension. There was a decrease in oxygen diffusion rate at less than 30 percent moisture because of discontinuity of moisture films.

Soil physical characteristics of each horizon in the soil profile have a controlling influence on the soil and water management requirements of that soil for crop production. During 1959, such characterizations were completed for 65 selected soil types in the Eastern half of the country. This included 22 profiles in Maine, 12 in New Jersey, 11 in Georgia, 16 in Louisiana, and 4 in Missouri.

Physical characterization of the peat area being utilized in subsidence studies at Belle Glade, Florida, were completed, and a series of water table elevation treatments were superimposed on the area. The area will now be cropped for several years and relationships between water table, crop response, and subsidence evaluated.

At Big Spring, Texas, artificial compaction of Amarillo fine sandy loam increased density from 1.5 g. per cc. to about 1.8 g. per cc. Intake rate was reduced to about 25 percent of the original value and roots of seven crops failed to penetrate the compacted zone. In other soil compaction studies, work at Bushland, Texas, and Fort Collins, Colorado, continues to indicate the suitability of waxes as a test medium in studies of root penetration. In such studies at Bushland, legumes showed no better penetrating ability than other crops.

At Mandan, North Dakota, soil froze to a 4-foot depth on dry and medium moisture plots and to only 3 feet on wet plots. Freezing was approximately two and one-half times as deep without snow cover as where a heavy snow cover was present. Thawing in the spring occurred from the bottom up on dry and medium plots and from the top down on wet plots. Date of complete thawing of the profile was 18 days earlier on dry than on wet plots.

Although preliminary, these experiments show that through selective fumigation it may be possible to improve soil aggregation by developing conditions favorable to desirable microorganisms.

No apparent benefits were obtained from subsoiling and deep placement of lime and fertilizer on Ashby shaly silt loam at Oldtown, Maryland. The corn crop suffered from drought on all plots. Similarly deep tillage and deep placement of lime and fertilizer gave negative results on the Coastal Plains in New Jersey.

Exploratory studies at Ithaca, New York showed that addition of certain silicones to the soil markedly increased aggregate stability and decreased capillary movement of water.

Plans: This work will be continued with emphasis on basic studies to characterize physical, chemical and biological forces involved in soil structure formation.

Publications: Soil Bulk Density Changes Due to Moisture Changes in Soil. W. R. Gill. Trans. of the ASAE. 2(1): 104-105. 1959.

Soil Compaction by Traffic. W. R. Gill. Agri. Eng. 40(7): 392-394, 400-402. July 1959.

4. MOVEMENT OF WATER INTO AND THROUGH SOILS SWC

Problem: Provide a basic understanding of the complex interrelations of factors which influence movement of water into and through soils and get a better understanding of soil and water management practices which influence the soil's ability to receive and store water from rainfall or irrigation water.

Program: A continuing program of investigation of the fundamental principles involved in water entry and transmission in porous media, carried on in eight states, cooperative with State agricultural experiment stations, and involving about four professional Federal man-years annually, and a contract with Purdue University.

Progress: The effect of temperature on the physical properties of water in soil is under investigation. The rate of water movement in soil can be expressed either in terms of soil-water diffusivity or capillary conductivity. The effect of temperature on diffusivity during water uptake by saturated- and air-dry soils has been measured. Near saturation, the viscosity effect is predominant and the water-movement rate increases with rise of temperature. At low water contents, the effect of temperature on matrie suction becomes important and in some cases exceeds the viscosity effect on flow rate. For many purposes, it may be acceptable to assume that the soil-water flow rate is substantially independent of temperature, at least in the soil temperature range that is suitable for crop growth. The effect of temperature on the total suction of water in soil is another matter and is in process of investigation. These advances in the study of the soil-water plant system will aid materially in the understanding of the movement of water in soil and into plant roots.

The chemical composition of the soil solution is of great agronomic importance. Experimental and theoretical work dealing with the removal of the equilibrium solution from soil suspensions has been continued. Due to the interaction of the electric fields of neighboring soil particles, especially at high clay content and low salt level, the composition of the filtrate of the suspension may differ considerably

from the true equilibrium solution. Theoretical expressions are now available describing the composition of the filtrate collected from clay suspensions as a function of the amount of filtrate under various conditions. Experimental evidence in support of the theory has been obtained. The work carries significant practical implications.

Of importance is the question whether the adverse effect on plant growth accompanying an increase of the total salt level is due to the lowering of the activity of the water in the root environment, or to a physiological reaction of the plant induced by an excess of ions entering its system. A search was initiated for a physiologically inert substance that could be used to increase the osmotic pressure of aqueous ionic culture solutions.

Carbowax 20M, a polyethylene glycol of high molecular weight, upon purification, was found to fit the requirements. Kidney bean plants were grown in culture solutions containing ions only and in those containing ions as well as Carbowax. Preliminary data indicated that plants harvested from Carbowax-containing solutions yield more than plants harvested from isotonic solutions containing ions only. The inference is that, beyond a certain value for the total salt level of the ionic environment of the roots, the growth depression due to osmotic effects is augmented by that due to specific-ion effects. These adverse specific-ion effects are distinguishable at relatively low salinity levels.

Plans: The importance of this work makes continued growth and development of these studies essential. Wherever possible, it will be strengthened by shifts in emphasis by personnel at key locations.

Publications: Rate of Water Intake Varies With Time of Season. W. E. Larson. Crops and Soils 12(4): 13-23. January 1960.

Water Intake Rates of Shelby-Grundy Soils from Hydrograph Analyses. V. C. Jamison and J. F. Thornton. Trans. Amer. Soc. Ag. Engr. 2(1): 92-94. 1959.

5. SOIL ORGANIC MATTER AND NITROGEN TRANSFORMATION SWC

Problem: More information is needed on the best methods of utilizing crop residues in order to produce the most favorable soil conditions and the most efficient utilization by crops of nitrogen sources available to them. Basic information on the chemistry and transformation of organic matter and nitrogen in soils is essential for maintenance of soil structure and for efficient production.

Program: A continuing program at Beltsville, Maryland, and in cooperation with the Colorado, Oregon, North Carolina, and Iowa Experiment Stations. Laboratory research is conducted on methods of extraction and characterization of organic matter and nitrogen complexes and their transformation under various simulated environmental conditions of moisture, temperature, kind and quality of plant residue, and clay components of soil. Soil samples from a broad array of soil management and climatic conditions are

examined to determine relationships. It involves about six professional man-years annually.

Progress: The mechanism by which organic matter improves soil aggregation is being investigated. Electrophoretic methods are being used and are very satisfactory as a means of isolating and characterizing homogeneous, high molecular weight organic compounds from soil organic matter. Continuous paper electrophoresis experiments have shown that extracts of soil organic matter can be resolved into several components in sufficient quantity for identification and use in soil aggregate stability studies. A column electrophoresis apparatus has been developed that can be used in conjunction with standard biochemical techniques to characterize fully soil polysaccharide constituents. Bacterial polysaccharides have been prepared from pure cultures and shown to have appreciable soil aggregate stabilizing effects. Results from this study represent the first step toward understanding the mechanics of soil structure formation.

The effects of drying and freezing of soil on the decomposition of organic matter and the water stability of the aggregates are being investigated. Results obtained to date show that the rate of decomposition of native soil organic matter is markedly higher when the samples are subjected to intermittent wetting and drying than when subjected to freezing and thawing. Wetting soil samples under vacuum in order to eliminate the disruptive action of the entrapped air, did not materially decrease the rate of organic matter decomposition as compared with samples wetted under normal pressure. In experiments involving intermittent wetting and drying with intervening incubation, the soil samples wetted at ten-day intervals showed substantial increase in the rate of organic matter decomposition in comparison with those that were rewetted after 24 hours.

Experiments designed to furnish practical information on the use of sawdust for soil improvement have been in progress. In preliminary tests a suitable method for determining carbon dioxide evolution was developed and many details of incubation procedures were worked out. Under conditions of air saturation with moisture, as occurs in a closed system, shortleaf pine wood particles that barely passed through a 6-mesh sieve decomposed about as rapidly as did smaller ones; likewise, particles left on the soil surface decomposed nearly as rapidly as when mixed with the soil. Such rapid decomposition on the soil surface would not occur under field conditions where the sawdust particles would be dry much of the time. Nitrogen additions sufficient to make the nitrogen content of the pine wood 0.75 to 1.0% were adequate under the experimental conditions for a maximum rate of decomposition in a low-nitrogen sandy soil. This value would vary with the ability of the soil to supply nitrogen; in a soil abundantly supplied with available nitrogen, additions of fertilizer nitrogen might not produce any increase in rate of decomposition of the sawdust. The sawdust would, nevertheless, convert a portion of the available nitrogen into unavailable forms and probably decrease crop yields. Nitrate and ammonium were equally good nitrogen sources provided the soils did not become excessively acid. During a period of 160 days with adequate nitrogen supplied, 58% of the pine wood carbon was released as CO_2; the

corresponding value for wheat straw was 64%. Shortleaf pine sawdust can, therefore, be classed as one of the most rapidly decomposing types of sawdust.

A chamber for tagging growing plants with C-14 (radioactive carbon) at any desired level of activity was constructed and put into operation. This chamber, which is nearly automatic, has been in successful operation for a period of four months. In the immediate future, it will be used primarily for tagging plants for later use in green manure and similar types of research.

At Corvallis, Oregon, native fixed ammonium has been found in all horizons of all soils examined ranging from a few to greater than 100 parts per million of nitrogen and constituting from 1 to 42 percent of the total soil nitrogen in the respective horizons. The results suggest that the long established generality that most of the total soil nitrogen is in organic combination needs modification. In light of present data, inorganic nitrogen may comprise the substantial part of the total nitrogen in the horizons of many soils. Organic carbon to organic nitrogen ratios calculated on more than 70 profile samples from the Pacific Northwest showed a range from less than 5 to greater than 15 indicating considerable variations in kinds as well as quality of soil humus. The results do not support the widely held concept that all soil humus tends to reach a condition of constant composition having C/N ratios within narrow limits, around 10 to 1.

Previous studies indicate that organic matter, extracted from different soils by a sodium-dispersion procedure, exhibited detectable differences in structure-stabilizing properties when these extracts were applied to a soil having very poor structure. Assuming that these observations reflect differences in the chemical nature of organic matter present in different soils, attempts were made to relate these observed differences to the polyuronide, or microbial gum, component of organic matter by using two methods of analysis for the uronide constituents. One method involved the well-known decarboxlyation principle of boiling the soil in 12 percent hydrochloric acid, and the other involved a recently developed method of alkali extraction, precipitation, and colorimetry. Present evidence indicates that the decarboxylation method detects carbon compounds in soils other than uronic carbon, and, therefore, this method gives highly erroneous values for the polyuronide content of soils. Studies have not progressed far enough to determine the usefulness of the colorimetric method for appraising the relationship between microbial gum production during organic matter decomposition and changes in soil structure resulting therefrom.

In an attempt to further our fundamental knowledge of what happens to fertilizers applied to soils, detailed laboratory experiments are in progress. Results from Fort Collins, Colorado, show that following additions of inorganic nitrogen to straw amended soil, practically all of the changes in inorganic nitrogen can be accounted for by changes in the soil amino acid fraction. These amino acids appear to make up the

active fraction of the soil nitrogen. However, only a portion of the total amino acid pool appears to be active. A possible hypothesis is that the active fraction of nitrogen in the soil consists of amino acid content beyond that which is absorbed on the clay minerals. Studies with labeled tracer nitrogen N^{15} show that the various soil nitrogen fractions do not tend to become uniformly labeled when tracer nitrogen is applied. These data strongly suggest that the soil organic components cannot be considered as one homogeneous pool of nitrogen.

Plans: Work will be continued with emphasis on (1) a study of accelerated oxidation of soil organic matter by additions of green manure crops; (2) causes of inhibition of plant growth sometimes observed following heavy applications of fertilizer and organic matter; and (3) studies on the release of available nitrogen from soil organic matter as affected by the rhizosphere bacteria. These studies have been greatly helped and accelerated by the acquisition of a Mass spectrometer and a Carbon 14 growth room in the Beltsville laboratory.

Publications: Relative Rates of Mineralization in Soil of Organic Nitrogen from Several Forage Crops. E. H. Stewart. Agronomy Journal 51: 51-53. 1959.

Wet Combustion Apparatus and Procedure for Organic and Inorganic Carbon in Soil. L. E. Allison. Soil Sci. Soc. Amer. Proc. Jan. - Feb. 1960.

A Convenient Apparatus for the Quantitative Estimation of Carbon Dioxide in a Carrier Stream. L. E. Allison. Soil Sci. Soc. Amer. Proc. July - August 1959.

Soil Fertility Studies in Lysimeters Containing Lakeland Sand I. F. E. Allison, E. M. Roller and J. E. Adams. U.S. Dept. Agr. Tech. Bul. 1199. 1959.

Rates of Decomposition of Shortleaf Pine Sawdust in Soil at Various Levels of Nitrogen and Lime. F. E. Allison and R. G. Cover. Soil Sci. 89: 194-201. 1960.

6. GASEOUS LOSSES OF NITROGEN FROM SOILS SWC

Problem: Develop an understanding of mechanisms involved in the loss of nitrogen through transformation processes to gaseous forms.

Program: A continuing program of evaluation of the extent and severity of nitrogen losses, causative factors and remedial measures through laboratory, greenhouse, and field studies in 5 states, cooperative with State agricultural experiment stations, and involving about 4 professional man-years annually.

Progress: In denitrification studies conducted at Raleigh in cooperation with the North Carolina Experiment Station, progress was made in the determination of the mechanism of the denitrification process. In this work, soils were maintained in a closed system where the gases were internally circulated, and gas samples were removed at intervals for

analysis in the mass spectrometer. It was found that the first gaseous product formed by reduction of nitrate was nitric oxide. The quantity of this gas that accumulated was always less than 5% of the added nitrate and was closely associated with the occurrence of nitrite. Undoubtedly, it was a decomposition product of nitrous acid in the acid soil used. As the second gaseous product, nitrous oxide, appeared, the nitric oxide began to disappear. The third gaseous product was nitrogen gas, and this was formed as a reduction product from the nitrous oxide. The nitrogen gas increased in amount sufficient to account for 83 to 95% of the added tagged nitrate. The data showed that no measurable amount of nitrogen gas was formed by the Van Slyke reaction, thus confirming the conclusions drawn from earlier studies conducted at Beltsville. These studies also confirm previous Beltsville findings that gaseous losses of nitrogen can occur rapidly and in quantity under conditions of very deficient soil oxygen if growth conditions are suitable for denitrifying bacteria, and nitrites or nitrates are present.

Studies have also been initiated to determine the extent and mechanism of loss of nitrogen following the application of large amounts of ammonium sulfate to well-aerated soils. It was found that the losses usually increase with increase in additions of both ammonium sulfate and calcium carbonate, and are greatest on the coarser textured soils. Some of the nitrogen escapes as ammonia but most of the loss is in other forms, probably as nitrogen gas and oxides of nitrogen formed from nitrites during nitrification.

Limited work on ammonium fixation during the year dealt largely with methods of determining fixed ammonium apart from free and exchangeable ammonium. No definite conclusions can be given at this time but an equilibrium procedure using N^{15}, and also a method involving the digestion of a soil with hydrogen fluoride, merit further study.

Vegetative tests indicate that most of the ammonium that is added to a soil having a high fixation capacity is available to crops, whereas the small portion not removed by the first crop is largely unavailable to a second crop.

Detailed controlled laboratory experiments at the Nitrogen Laboratory, Fort Collins, Colorado, with well-aerated grassland and intertilled soils have shown that nitrogen losses are greatest on the grassland soils. There appears to be a direct relationship between nitrite accumulation and the magnitude of nitrogen deficit. Gaseous losses of nitrogen in incubated soils have now been linked to dissimilar nitrifying capacities, to nitrite accumulation and to pH values. Nitrous acid instability rather than enzymatic denitrification of nitrate or volatilization of ammonia appears to be primarily responsible for large gaseous losses on many well-aerated soils. Gas chromatography studies have shown no evidence of loss of nitrogen as nitric oxide or as nitrogen dioxide. In soils the reaction between ammonium and nitrite ions to form nitrogen gas does not seem to be as important as the reduction of nitrite to nitrogen gas by some component of the soil complex. It appears that the yet unidentified soil

component associated with high gaseous losses of nitrogen is an organic compound. Inefficient use of nitrogen fertilizer on rangeland soils might well be linked to differences in organic constituents of grassland soils as compared to cultivated soils.

Plans: Studies will be continued to (1) determine the conditions that favor gaseous losses of N from various types of fertilizers, magnitude of the losses, and how to avoid them, (2) determine the mechanism of the process, (3) attempt to evaluate these losses under field conditions using N^{15}.

Publications: Losses to the Atmosphere of Applied Fertilizer Nitrogen. F. E. Clark. Proc. 1959 Fert. Eval. Conf., Wilson Dam, Alabama. 15-16.

Dissimilar Nitrifying Capacities of Soils in Relation to Losses of Applied Nitrogen. F. E. Clark, W. E. Beard, and D. H. Smith. Soil Sci. Soc. Amer. Proc. 24(1): 50-53. Jan. - Feb. 1960.

Use of Gas-Solid Chromatography for Soil Nitrogen Studies. F. E. Clark and D. H. Smith. Agron. Abstracts. Nov. 16-20, 1959.

The Effect of Partial Pressure of Oxygen on Denitrification in Soil. F. E. Allison, J. N. Carter and Luann D. Sterling. Soil Sci. Soc. Amer. Proc. 24(4): 283-285. July-August. 1960.

7. SOIL MICROBIOLOGY SWC

Problem: The effects of method of residue management and of irrigation on microbial activity and survival in agricultural soils is inadequately understood for development of the most efficient soil and water conservation systems. The mechanisms and economic significance of the bacterial-induced chlorosis in soybeans needs determining, a temperate bacteriophage for genetic studies with legume bacteria needs discovery, commercial preparations for preinoculated legume seeds need evaluation, and new strains of legume bacteria should be sought and tested.

Program: A continuing program involving basic and applied research on the inoculation of legumes, microbiological processes in soils, bactericidal activity of antibiotics in soil and synthetic soil complexes. Much of the work is cooperative with several state experiment stations and involves about eight professional man-years annually.

Progress: Attempts to obtain a temperate bacteriophage for use in transduction studies with *Rhizobium* have continued. The screening program consists of selecting strains of rhizobia representing groups of widely divergent types and plating them against each other to see if cell destruction (lysis) is produced. Although no temperate phages have been found in the cultures tested to date some progress has been made in developing a better method of checking for fermentative mutants and in characterizing the gum produced by these bacteria. The gum is of interest because the polysaccharide could possibly serve as a genetic marker, or

the gum might be inhibitory to phage adsorption. Failure to obtain a temperate phage may be due to their rarity, which seems unlikely; to presence in rhizobial strains of prophages that are closely enough related to give immunity; or the temperate relationship may be so highly developed within those strains where it occurs that only extremely weak lysis is obtained.

In cooperation with the Crops Research Division, studies on differential competition between genotypes of Rhizobium have been continued using bacterial-induced chlorosis as a means of distinguishing strains. Competition between genotypes of Rhizobium japonicum was studied using two chlorosis-inducing strains which were individually mixed in varying proportions with each of nine normal strains and mixtures used as inoculants on Hawkeye and Lee varieties of soybeans. One chlorotic bacterial strain had a pronounced advantage over all normal strains regardless of the proportions of the strains in the mixtures. As little as 1.1% of this chlorotic strain produced 85% of the nodules. There was considerable difference in competitiveness among both chlorotic and non-chlorotic strains. The extent of chlorosis of the soybean plants gave a rough estimate of the competitive relationships between strains.

Purification and characterization of the chlorosis-producing substance obtained from soybeans is continuing. A 340-fold concentration of the compound from the original crude water-extract has been achieved. It has a molecular weight of less than 1000, is positively charged, heat stable, insoluble in common organic solvents and appears to have chemical properties similar to those of an amino acid or a low molecular weight amine.

During the past year there has been much interest in preinoculation of legume seeds as a result of considerable advertising by seed growers and commercial producers of inoculants and the offering for sale of such products by them. Several samples of one of these products, known as "Noculized" alfalfa, have been tested at Beltsville over a period of months. These studies showed that under the conditions of storage and test used the bacteria remained active for a period of only 3 to 4 months. A period of at least six months is usually required to market alfalfa seed through ordinary trade channels.

"Phosphobacterin", a bacterial inoculant obtained from the U.S.S.R., is widely used in that country for mineralizing phosphorus from the soil organic matter for use by both legume and nonlegume crops. This inoculant was evaluated in two greenhouse experiments. Radiophosphorus was used in a portion of the pots to increase the accuracy of the test. In the first experiment, six soil types that were either neutral or limed to near neutrality were selected and planted to tomatoes and wheat. A 7.5% increase in yield was obtained with tomatoes but none with wheat. There was no effect on phosphorus uptake by either crop. In the second greenhouse experiment, tomatoes were grown on four soils using three levels of radiophosphorus and 0 to 10 tons of manure per acre as variables. The inoculant had no effect on tomato yields or release of phosphorus from the soil organic matter. Phosphobacterin was also tested under field conditions at

Palmer, Alaska; Morris, Minnesota; Bozeman, Montana; Mandan, North Dakota; and Bushland, Texas. Oats were grown at the first four of these locations and grain sorghum at the Texas location; radiophosphorus was not used. The only significant increase in yields at any of the locations was a 15% increase at Mandan, North Dakota, in oat forage harvested at the 14-inch height stage; no difference was found at later harvest of forage and grain. The conclusion reached is that phosphobacterin has little potential value under our conditions. In fact, its value anywhere may be questioned.

The comparative rates of decomposition of corn stalk residues placed on the surface or buried in the soil under Iowa climatic conditions was determined. During the first 40 days about seven times more decomposition (35% vs 5% loss in dry weight) occurred in the buried residues than in those left on the soil surface; after 139 days the corresponding difference was less than two times (65% vs 35%). The total nitrogen content of the buried residues increased somewhat during the first month but some of the nitrogen was released later. The surface residues gained in nitrogen but retained it throughout the duration of the experiment. The amount of nitrogen immobilized by three tons per acre of corn residue was about 8 to 18 pounds per acre. This could account for only a portion of the depressing effect of surface-applied residues.

Denitrification studies in soils maintained in the laboratory lead to the conclusion that loss of nitrogen by this process is of minor importance in soils that are kept strictly aerobic, but under field conditions this ideal condition may not exist at all times, even in loose, open soils. Some losses were observed where 1 to 3% dextrose was added, but wheat additions did not increase gaseous losses of nitrogen. In studies where soils were aerated with oxygen-nitrogen mixtures, some significant losses of nitrogen added as nitrate occurred at a partial pressure of 2.2% oxygen; with 0.46% oxygen the losses ranged up to 10% of the added nitrate in the absence of an added energy source, and up to 50% with 0.5% glucose.

There is considerable uncertainty concerning the production, activity and ultimate fate of antibiotics in soils. Previous work in this laboratory with protein-montmorillonite complexes suggested that some of the uncertainty might be clarified by studying antibiotic clay complexes. As an initial effort the extent and mechanism of adsorption of antibiotics by various clay minerals and soils was determined. It was found that the ten antibiotics studied could be divided into three groups according to their reactions with clays, namely (1) strongly basic (streptomycin, dihydrostreptomycin, neomycin and kanamycin), (2) amphoteric (bacitracin, aureomycin and terramycin), and (3) acid (penicillin) or neutral (chloramphenicol and cycloheximide). The first two groups react to varying degrees to form complexes with montmorillonite, vermiculite, illite and kaolinite. Only montmorillonite adsorbs and holds the acidic or neutral antibiotics, and then only in small amounts. The amounts of the various antibiotics that are adsorbed by the different clays vary from an average of 318 mg. per g. of clay for the amphoteric antibiotics on montmorillonite to 9 mg. for the strongly basic ones on kaolinite. X-ray diffraction data for the antibiotic-montmorillonite complexes gave an

average expansion of the c-spacing of about 4.4 A. for the strongly basic antibiotics, and 7.6 A. for the amphoteric ones, corresponding to mono-layers and di-layers, respectively. In similar studies with vermiculite, the streptomycin, neomycin, kanamycin, aureomycin, and terramycin were adsorbed to a lesser extent, only partially filling the interlayer spacings. Adsorption studies with soils, similar to those described above, showed that the clay minerals in them reacted with antibiotics just as do the corresponding comparatively pure minerals.

Biological tests for the bactericidal activity of the complexed antibiotics are in harmony with the data obtained in the physico-chemical studies. The strongly basic antibiotics, with one exception, were not released from montmorillonite, vermiculite, and illite but were released to varying degrees from kaolinite; the amount of neomycin and kanamycin released was very small, if any. The amphoteric antibiotics, however, were released from all four clay minerals in varying amounts. Assays of antibiotics-soil complexes gave results that agreed closely with expectations based on their clay mineral contents. By means of appropriate buffers, it is possible to determine to some extent the types and approximate amounts of clay minerals present in a given soil if the organic matter content is low. Antibiotic-clay complexes were shown not to diffuse through agar but the antibiotic is first released by an exchange reaction with the buffer and then diffuses through the agar. Less than 1 mg. of terramycin per gram of non-sterile clay or soil could be detected readily without interference from the normal soil population.

At Prosser, Washington, a continuous flow dilutor was developed to facilitate counting of soil organisms. It consists of a chamber with a magnetic stirrer into which diluent is fed and sample withdrawn. The concentration of the effluent is a logarithmic function of the volume delivered. The apparatus will greatly facilitate soil microbial assays by enabling a very wide range of dilution or by selection of appropriate ranges so that plate counts are more accurate. Laboratory studies showed that pentachloronitrobenzene (PCNB) used on three soils at rates varying from 0 to 220 ppm. had no inhibitory or stimulatory effects on numbers of soil organisms or on carbon dioxide evolution rates even when glucose as an energy source was supplied. The specific activity of PCNB as a fungicide cannot be shown by such general tests as plate counts and soil respiration.

Some microorganisms such as Stachybotrys atra have been found to improve soil aggregation. In laboratory studies when this organism was introduced in the sterilized soil material with straw as an energy supplying material, a high degree of aggregation was obtained. About four times as much aggregation was produced with S. atra as with mixed soil flora. The use of a fumigant UF-85 (urea 26 percent, formaldehyde 59 percent) killed all organisms except a Fusiarism-like fungus which was a very effective soil aggregant.

Plans: Work on the bacterial-induced chlorosis in soybeans will be continued in both laboratory and field investigations. The search for a temperate bacteriophage will be intensified and studies will be initiated to discover the reasons why preinoculated legume seed is effective up to six months after treatment. New preinoculated processes will be investigated. The other microbiological work will be continued at about the same level.

Publications: Responses of Seedlings to Extracts of Soybean Nodules Bearing Selected Strains of Rizobium Japonicum. H. W. Johnson, Ura Mae Means and Francis E. Clark. Nature 183: 308-309. 1959.

Influence of the Microbial Population of the Rhizosphere on Plant Development. F. E. Clark. Proc. 9th Internat. Botanical Cong. 2(74). Aug. 1959.

Occurrence and Transfer of a Biological Factor in Soil that Suppresses Potato Scab. J. D. Menzies. Phytopathology 49(10): 648-652. Oct. 1959.

Microorganisms and Their Activity with Crop Residues. T. M. McCalla. Nebr. Agr. Exp. Sta. Bul. SB 453: 1-31. Dec. 1959.

8. MINERAL INTERRELATIONSHIPS IN SOILS AND ANIMAL NUTRITION SWC

Problem: To improve human nutrition by discovering relationships between soils, plants, and animals that will enable farmers to adopt economic combinations or practices for soil management, and crop and animal production, that will meet human nutrition needs.

Program: A continuing long-term program to expand fundamental knowledge of the relationship of soils to the nutritional qualities of plants and to the metabolic processes in animals and man consuming the plants. Work is carried on at the U. S. Plant, Soil and Nutrition Laboratory, Ithaca, New York, involves cooperation with several State agricultural experiment stations and about 11 professional Federal man-years annually.

Progress: White muscle disease in calves and lambs has been reported from widely separated localities in the United States and its occurrence appears to be related to specific areas. To test the hypothesis that a below average level of selenium occurs in forage in white muscle disease areas, a survey of ranches in Oregon, Idaho and Montana was made in cooperation with staffs of the State Experiment Stations. About 170 samples from 45 ranches representing 20 forage species were obtained, some from affected ranches, others from ranches having no history of the trouble. Since no reliable method for the estimation of quantities of selenium less than one ppm. was available, such a method was developed utilizing a recently published colorimetric determination for small quantities of the element. The data obtained indicate that the total quantity of selenium in samples from disease-free and from white muscle disease areas does not differ significantly and ranges from 0.21 to 1.7 ppm. of selenium in the dry forage. This level is considerably above the quantity of selenium reported to have prevented white muscle disease when a soluble salt of the element was added to the ration of sheep. It is possible that the total selenium

in plant tissue is not in a form effective in preventing this trouble or that in some areas some other element or component of the plant is interacting with selenium and interfering with its normal metabolism. These possibilities will be investigated further.

Work on the "crooked calf" problem in Idaho has also continued in cooperation with ADP. On the supposition that lead or some other heavy metal might be ingested by cattle in toxic amounts from water, a large number of waters were analyzed. The results so far have been negative. However, a typical crooked calf was produced by feeding a heifer a combination of lead and lupine. Further investigation of the toxicity of lead or lupine will be conducted as well as the effect of other mineral elements such as copper, zinc, arsenic and telurium.

A problem of low productivity in animals has long characterized the southeastern counties of Kansas. In cooperation with the Kansas Station about 230 samples of 33 species of forage and weeds were selected in the summer of 1959 from 34 sites representing the principal soil types of the region. These sites had previously been selected with the assistance of the Soil Conservation Service. Cobalt, copper, zinc, manganese, potassium, sulfur and iron were determined on all samples and lead and selenium on a selected group. Molybdenum analyses are underway. The data show a general deficiency of cobalt throughout the nine county area.

Changes in distribution and amounts of cobalt associated with iron were investigated in cooperation with the Soil Conservation Service. Coarse textured soils, sands and loamy sands, were selected because they reflect striking differences in distribution of iron as well as humus in their morphology. Sandy soils representative of three great soil groups - Regosols, humus Ground-Water Podzols and Humic-Gleys - were obtained in southeastern United States; soils of five great groups - Podzols, Brown Podzolic, humus-iron Ground-Water Podzol, Low Humic-Gley and Humic-Gley soils - were obtained from northeastern United States. The distribution of cobalt most closely paralleled that of iron in soils that had well expressed B horizons (Podzols, humus-iron Ground-Water Podzols and humus Ground-Water Podzols), and least closely in the Low Humic-Gley and Humic-Gley soils of northeastern United States. The amounts of cobalt and iron were larger in the sandy soils of the Northeast than in soils of similar texture of the Southeast. The amounts of cobalt and iron in the northeastern soils appeared related to the glacial drift origin of the soil parent material. The generally low amounts of iron and cobalt in the sandy coastal plain soils of the Southeast are attributed to the weathered nature of the parent material, all of which had undergone one or more cycle of weathering prior to deposition. Weathering processes that result in the formation of Podzols, Brown Podzolics, and humus-iron and humus Ground-Water Podzols appear to affect the cobalt-iron relationship in a like manner.

Investigations into the nature of the reactions between heavy metals and silicate minerals continued. With cobalt the presence of at least two types of specific reactions, one exchangeable with other heavy metal ions,

the other not exchangeable, has already been noted. A third mechanism of reaction which is characterized as being nonexchangeable with other heavy metal ions but which can be extracted with 2.5% acetic acid is now also observed. The latter form contributes only slightly to the sorption of cobalt by montmorillonite but appears to be more significant with other 2:1 layer silicates. Comparison of the two forms observed initially with montmorillonite indicates that the two remain almost directly proportional to one another with changes in pH or solution concentration of cobalt, although the relative proportion of each changes markedly with time or pretreatment of clay. The possibility that the different mechanisms are related structurally is being investigated.

Characterization of the reactions that takes place between cobalt and various silicate minerals has revealed that the bonding energy varies considerably with surface coverage. Thus for soils of constant mineral composition and pH the lower the level of cobalt the more strongly it is bound. At least in the case of reactions with montmorillonite there appears to be considerable hysteresis in the sorption reaction. The variations in bonding energy and the presence of hysteresis suggests that classical methods of characterizing the reactions will be of only limited value. The use of radio-autography shows promise of providing information as to the nature of the reactions that take place. Radioautographs were prepared of 2 to 5 mm vermiculite particles that were allowed to combine with Co^{58} in the presence of 0.1N $CaCl_2$. Most of the cobalt sorbed by vermiculite was associated with edges, cracks, or other obvious crystal defects. However, only a small fraction of these features were actually involved in this sorption. An additional curiosity is that cobalt was not usually concentrated immediately at the edge or crack. Thus two dark bands may be found on either side of a crack with a clear area in between. Some of the sorbed cobalt could not be associated with observed crystal surface uniformly while the remainder was concentrated in small localized areas on the basal surfaces of the mineral. The latter fraction is likely to be associated with crystal defects resulting from injury or axes of screw dislocations that cannot be observed with the light microscope. A degradation approach is being developed to determine the chemical associations of cobalt and other heavy metals in soils to evaluate the relative contribution of different soil constituents in combining with various heavy metals in the field.

Plans: Investigations will be made of the interrelationships of high levels of supply of the fertilizer elements such as nitrogen, phosphorus, potassium, boron and zinc with other mineral nutrients in food and feed crops and with other dietary constituents. Feeding studies of nutrient quality of plants affected by imbalance of mineral nutrients in the soil will be continued.

Publications: An alanine-dependent, ribonuclease-inhibited conversion of adenosine 5'-phosphate to adenosine triphosphate. II. Reconstruction of the system from purified components. R. W. Holley and J. Goldstein. Jour. Biol. Chem. 234: 1765-1768. 1959.

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Plant and Soil Analysis in the Evaluation of Micronutrient Element Status. K. C. Beeson. In Mineral Nutrition of Trees, Duke University School of Forestry, Bul 15: 71-80. 1959.

Countercurrent Distribution of Rat-Liver, soluble-fraction ribonucleic acids. R. W. Holley, B. P. Doctor, Susan H. Merrill, and Farida H. Saad. Biochim. Biophys. Acta 35: 272-273. 1959.

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9. IMPACT OF PESTICIDE RESIDUES IN SOIL SWC

Problem: The accumulation of pesticide residues in soils and plants is rapidly becoming a national problem as a result of the tremendous tonnages of organic insecticides, nematocides and herbicides now being used. Buildups in the soil of pesticide materials or their decomposition products may harmfully affect crop growth, or impair flavor, quality and palatability of food products and feed as a result of absorption of the chemicals by the growing crop.

Program: This is a long-term program involving fundamental research on the myriad of pesticides to learn their fate and ultimate reactions with soil components and requires initially the services of about 3 professional Federal man-years annually.

Progress: Studies suggest that antibiotics may be more prevalent in soils than was generally supposed, but are not released by the usual laboratory techniques. In urease-clay complex studies, it was determined that H-montomorillonite completely adsorbed varying quantities of urease, leaving a supernatant liquid that showed no urease activity. Similar tests with untreated basic montmorillonites showed complete adsorption in only one case. H-kaolinite did not adsorb and hold all of the urease at

any of the concentrations used. There was no significant difference between the urease activity of urease-clay complexes suspended in water or buffer because urea hydrolysis brought about an alkaline reaction regardless of the presence of buffer. Comparative activities of the various urease complexes, based on the activity of urease in aqueous solution as 100, were approximately as follows: H-montmorillonite 25, H-kaolinite 50, and untreated montmorillonite and kaolinite 66. Experiments showed that the inactivated urease, in the presence of urea, is gradually released from the clay and exerts its activity in solution. Initial release of the enzyme from the clay is attributed to urea acting as a cation. Subsequently, the ammonia evolved through its hydrolysis becomes the active cation. This concept was substantiated by experimental evidence. This type of mechanism seems to explain other observations reported in the literature involving the activity of enzymes and antibiotics in soils. Procedures used may be of real value in explaining pesticide behavior in soils.

Plans: Only a very minor part of this work has been undertaken as presently the only support comes through funds and materials diverted from other activities. Specifically, this involves initial study of the pesticide-clay complex interactions including a study of the mechanism of formation. In addition to a survey of past research applicable to the problem, a preliminary study will also be made of the fate of soil-surface applied pesticide through analysis of runoff and soil loss samples resulting from simulated rainfall applied to test plots.

10. DYNAMICS OF WATER IN PLANTS SWC

Problem: An understanding of the interrelationships of soil-water and plants is basic to an efficient agriculture and to the conservation of soil and water resources.

Program: A continuing program involving the dynamics of water in plants and the response of plants to water deficits and using about 6 professional Federal man-years annually.

Progress: Studies are underway in Illinois, Georgia, New York, Wisconsin, New Jersey, Minnesota, North Carolina, and Maryland to determine fundamental soil-water-plant relations and to develop principles which can be used to guide future field investigations in the area of irrigation and drainage practices and requirements. Lack of such fundamental information and principles greatly handicap development of improved practices.

Factors controlling the movement of water, nutrients, and oxygen through soil to the surfaces of plant roots received major attention in Illinois. There was considerable evidence to indicate that biological factors as well as physical factors influenced such movement. Increased moisture content caused an increase in ion transfer rate, but uptake of ions by roots and the accompanying concentration gradients that resulted had to be taken into consideration to explain the observed movement rate.

When soil temperature was raised from 15.5° C. up to 30° C., increased flow rates resulted from lowered viscosity of water. Increased metabolic activity also occurred at the higher temperatures which resulted in faster uptake of ions and steeper concentration gradients toward the roots. In like manner, as soil moisture content was increased and soil moisture tension was reduced, the increased growth rate of the plant at the more favorable moisture regime resulted in gradients toward the root.

Since most water transpired from plants moves through the stomates, attempts are being made to control the stomatal openings. A preliminary study of the mechanism of action of guard cells independent of photo-synthetic activity has been initiated. Albino plants of sorghum, tobacco, soybeans, and corn, cultured in sugar solutions, have made measurable growth. Attempts to control stomatal behavior by alteration of the pH of the sugar solutions have failed. Photomicrographic techniques have been developed for following stomatal changes that occur as light quality and energy levels are varied.

Absorption of ions through leaves was influenced by the moisture content of the soil in which the plants were growing. In Georgia, foliar absorption and translocation of P^{32} by bean leaves was eight times as great when plants were growing at moisture tensions near field capacity than at tensions near the wilting percentage. Autoradiograms indicate a marked decrease in movement of P^{32} throughout the plant at higher moisture tensions. The uptake of P^{32} by barley and pine seedlings from Cecil sandy loam was higher with decreasing soil moisture tension for all fertilizer levels.

Foliar application thus appears to offer some possibility for rather quickly altering the internal nutrition status of plants by external means whenever efficient use of soil and water so demands it.

Uptake of water by plant roots is opposed by the total soil-water suction which has two components. The matric suction is determined by molecular attraction between water and the soil surface and is related to the thickness of the absorbed water films. Solute suction is numerically equal to osmotic pressure and measures water binding by dissolved material in the soil solution. The thermocouple psychrometer, developed at the U. S. Salinity Laboratory at Riverside, California, for measuring vapor pressure, indicates the sum of these two effects and provides a research tool for quantitatively evaluating soil-water condition as a factor in crop production. The method is suitable for soil from humid areas where soil salts are usually negligible or for irrigated soil where salinity must often be considered. Working with porous ceramic materials during the past year, it was shown experimentally that a unit of matric suction is equivalent to a unit of solute suction as far as vapor pressure effect is concerned. For this material, where matric suction and solute suction can be independently controlled and measured, they were found to be additive to give total suction. Various interactions between matric suction and solute suction in soil are anticipated, but for the experimental conditions used which involved several soils at several salinity levels, it was found that the sum of the solute suction of the solution ex-

tracted from a soil paste and the matric suction of a pressure membrane on which the soil paste was placed for matric suction control, closely approximate the total suction of the soil sample as measured by vapor pressure.

Plans: This work will continue at about the same level.

Publications: Behavior of P^{32} in Tracer Studies. Sterling R. Olsen and Frank S. Watanabe. Soil Sci. 88(5). Nov. 1959.

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V. EROSION CONTROL

1. FUNDAMENTALS OF WATER EROSION SWC

Problem: Develop basic information on the mechanics of runoff and soil erosion from rainfall and establish fundamental principles to guide applied phases of the research needed to develop better erosion control.

Program: A continuing program of basic research in cooperation with nine state Agricultural Experiment Stations, involving about five professional Federal man-years annually.

Progress: Data for design of the drop application apparatus for laboratory simulators were secured at the Minnesota and New Hampshire projects. This information will be used in design of equipment for study of the mechanics of erosion and evaluation of the soil erodibility factor under controlled laboratory condition.

The erosion data indicated that in designing irrigation systems in areas that are subject to runoff from rainfall, some erosion can be expected when slopes of 0.6 percent are exceeded.

At Temple, Texas, a 2-inch gravel mulch on fallow kept runoff loss to less than 2 inches during 1959 as compared to 18 inches on a bare plot in which two-thirds of the soil surface was treated with waterproofing material. All mulch treatments whether with gravel or straw yielded little runoff whereas all bare treatments, whether a portion was waterproofed or not, resulted in high runoff. Waterproofing a portion of the surface increased runoff.

Plans: Work will continue on all active studies during the coming year. Studies dealing with mechanics of raindrop splash and on landflow erosion will be initiated at Morris, Minnesota, and Lafayette, Indiana, during the year.

Publications: Thunderstorms - The Principal Cause of Erosion in the Piedmont. A. P. Barnett, J. S. Rogers, and Carlisle Cobb, Jr. Ga. Agr. Res. 1(4). Spring 1960.

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2. SOIL FACTOR FOR USE IN PREDICTING EROSION RATES SWC

Problem: To develop tables, equations, and graphs for prediction of field runoff and soil losses.

Program: A continuing program to refine and evaluate the various components of a universal erosion prediction equation including the soil factor, slope, rainfall energy and management practices, in cooperation with the Indiana Agricultural Experiment Station and involving 3 professional man-years annually.

Progress: Major developments during 1959 at the Runoff and Soil Loss Data Summary Laboratory, Lafayette, Indiana were along four lines: (1) analysis of rainfall-erosion index data required for preparation of iso-erodent maps of the eastern 31 states, (2) preparation of rainfall-erosion distribution curves by months for determining local values of crop-management factors used in the new erosion prediction equation, (3) preparation of a table of relative soil loss values for various crop stage periods for each of 100 crop sequences under different soil productivity levels and management methods, for localized evaluation of the crop-management factor, and (4) summary of annual rainfall-runoff data from grain crop and meadow plots to provide information on water yields from agricultural lands. In addition, assistance and guidance was given the Soil Conservation Service and the College of Agriculture in Tennessee in development of maps and tables for use of the new erosion equation in preparing technical guides for conservation farm planning in the state.

Rainfall-erosion index values have been computed for 180 locations from U. S. Weather Bureau records and Soil and Water Conservation Research Division stations. For each of the locations, the annual mean and probability values for frequencies of once in 100, 20, 5, 2, and approximately 1 year were computed. These values will be used in preparation of iso-erodent maps of the United States. Corresponding values were computed for individual storms. With the individual storm and annual probability values, more realistic evaluations can be made of individual storm and individual year losses.

The average annual rainfall-erosion indexes increase from north to south. There is a pronounced southward dip in the iso-erodents in the western approach to and in the Appalachian Mountains. The maximum value in the eastern 31 states was 62 at Caribou, Maine. In the western states values ranged from 502 at Houston, Texas to 6 at Pendleton, Oregon.

With any annual grain or row crops, the effect of the growing crop and of crop residues varies significantly within the year. There are rough fallow, seedbed, establishment, growing, and residue or stubble periods. Soil loss during each period, in relation to loss under fallow with similar rainfall, soil and slope conditions, was determined at the Data Summary Laboratory from experimental measurements secured since 1930 from natural rainfall plots throughout the country. Grass and legume sod crops were found to have a residual effect on erosion under cultivated row crops that followed. The quality of the meadow as measured by hay yield proved to be a good criterion for the rate of loss under the following corn. The residual effect of the sod decreased each year and disappeared in most cases after the third year. Fertility applications or natural productivity that resulted in quick and abundant growth of crops, also reduced losses. Tillage practices and crop residue management also affected soil loss. These and other factors were considered in preparing the 100 line table of relative soil losses by crop stage periods. The local value of the cropping-management factor can be computed from this table, together with local monthly rainfall-erosion index distribution curves, cultural operation dates, cultural methods and expected crop yields. The 100 line table does not include values for all crop conditions, nor all of the new management practices. Current studies are securing this information.

The rainfall-runoff relationship secured from grain crop and meadow plot measurements provides generalized data on water yields from agricultural land by soil-climatic areas. Punch cards on file at the Data Summary Laboratory representing 6,159 plot years of data from 33 locations in the U. S. were analyzed last summer when need quickly arose for the information. One item from the analyses showed runoff from rotation meadow to average 43 percent of that from row and grain crops. If the runoff data had not been on punch cards at a central laboratory, this 124 line summary table could not have been prepared except by long and tedious work by numerous individuals.

Rainfall-erosion distribution curves by months were developed to adjust for difference in time of occurrence of erosion-producing storms in

relation to periods of varying protection within a crop rotation cycle. Curves have been prepared for each of the record locations. By plotting accumulated monthly erosion index values as percent of annual total, many curves are the same, although annual totals are different. As an example, in Tennessee only two curves were required--one for the mountain area in the east, and another for the area west of the mountains. For Indiana, data from 16 locations appear to fall into four natural groups. The greatest concentration of erosive rain for the central Indiana group was in June, while in the southern part of the state erosive rains occurred more often in the fall and winter. Thus, a cropping system with the soil bare only in June would allow more erosion in central Indiana than in the southern part of the state.

The cropping-management factor for the new erosion equation is the expected ratio of soil loss from land cropped under specified conditions, to that from clean cultivated fallow under identical soil, slope and rainfall. Clean cultivated fallow was selected as the reference common to all soil-climatic areas because soil loss under this condition was shown to have a high positive linear correlation with the rainfall-erosion index values.

Plans: Soil characteristics related to soil erodability and numerical evaluation of the soil factor in the universal erosion equation will be studied at the National Runoff and Erosion Data Laboratory, Lafayette, Indiana during the coming year. Soil loss records from fallow, continuous row crops and row crops in rotation now on file at the laboratory will be used for this purpose. Two laboratory rainfall simulations, one at Ames, Iowa and the other at Orono, Maine, will be installed to start similar studies on bench work soils of the North central and the Northeastern states during the 1960-61 winter.

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3. PRACTICES FOR CONTROL OF WATER EROSION SWC

Problem: Improved terrace, diversion, contour, and contour strip crop systems; better crop sequences and tillage practices; better practices for the establishment and maintenance of vegetation in terrace outlets and waterways; and effective gully control measures are needed for control of runoff and erosion on crop and range lands.

Program: A continuing program carried on in cooperation with 16 State experiment stations and involving about 14 professional man-years annually.

Progress: Soil erosion under minimum tillage was less than under conventional management on 5 soils in the 4 states in which it has been studied. The magnitude of the reduction varied between soils, slope, antecedent crop and rain severity. Minimum tillage did not always reduce runoff. Cultivation of the corn was an essential part of the method on soils that crust easily under impact of rainfall.

Freeze-thaw losses, surface flow, and sub-surface flow all apparently contribute directly to gully development in the river terrace areas of the Connecticut Valley. The relative importance of each of these is not apparent from currently available data. The bulk of the losses on the gullies studied so far has been confined to a period of about one week during the spring thaw. In one gully, 3,740 cubic feet of soil moved out of the gully head during the last two springs, and on another, 250 cubic feet. The larger loss represented an increased gully area of .03 acre.

A second Rainulator was completed and preliminary test runs made in Georgia, and a third completed in Minnesota. These Rainulators will materially speed evaluation of both old and new management practices for more effective use of the erosion prediction equation. New plot installations under natural rainfall are being limited to runoff and soil loss characterization of broad soil-climatic areas not previously studied.

In a study of row grades for strip cropping in Wisconsin during the last 8 years runoff averaged one-third inch per year greater from a watershed with 2 percent grade rows than from a watershed with level rows. Annual soil loss, however, averaged nearly a ton per acre less with the graded rows than with level rows, because of less row breakage and rilling during severe runoff storms. This was a soil loss reduction of over 40 percent.

Conservation cropping systems, parallel terraces and grass waterways on the three pilot farms at the Southern Piedmont Soil Conservation Experiment Station, Watkinsville, Georgia have provided excellent runoff and erosion control. Farming operations along the smooth contours of the parallel terraced fields proceeded rapidly without difficulty from the terraces. Elimination of the point rows common to the older terraced fields has reduced farming time.

The first years' results from a slope study in Mississippi indicate that the high rate of soil loss on moderately steep slopes in cultivated crops may be favorably modified by use of carefully graded rows which drain into a grass waterway. The corn rows were 150 feet long and on a 0.4 percent grade. Doubling the steepness of land slope increased the soil loss by only 85 percent, or about one-third the increase measured on short row contour plots in Georgia and Wisconsin, and on uphill and downhill tilled plots in New York. With graded rows, part or all of the runoff is carried by the row at non-eroding velocities to a grass outlet, but with the level contour row plots, runoff occurs when the rows overtop, allowing the water to flow directly from the slope. Increasing the slope length from

73 to 210 feet in New York increased the soil loss by 50 percent on a 5 percent slope, but on a 9 percent slope the increase was 100 percent, and on a 17 percent slope it was nearly 400 percent. These data emphasize the complex interrelations between length of slope, steepness of slope and row direction, grade and capacity which must be expressed mathematically for accurate application of conservation farming methods.

Study of methods for establishing vegetation in waterways was underway at two locations and on roadside areas at one location during the year. The waterway studies included use of plastic mulches and of companion crops for quick cover. The roadside studies included species adaptability and effectiveness of different mulch materials.

Crown vetch is the most promising perennial legume cover for roadbanks. It stays green for a greater period during the year than the grasses, thus reducing the fire hazard, and it does not need nitrogen fertilizer for growth. Its chief drawback is the relatively long development period for complete cover. So far, ground cover has not been secured until during the third year after planting. Two establishment methods have been developed that apparently overcome the seriousness of the slow development period. One method involves use of rye residues. Rye develops a quick cover and grows a heavy, anchored straw mulch. This has lasted until an over-seeding of vetch developed into a complete cover. The other method involves use of broomsedge residues which have been grown in place on fertilized road cuts of this project without seeding. Broomsedge has also been grown on fertilized slopes from seed in stalks of the plant applied as a light mulch.

Plastic sheet coverings on new seedings created both favorable and unfavorable conditions. Clear plastics gave better stands in early spring plantings on roadside areas in Georgia than white or yellow, but frequently resulted in serious sunscald during hot days. Maximum and minimum daily temperatures under clear plastic averaged appreciably higher than air temperature during spring and summer tests. Temperatures under white and yellow plastics were more nearly like the air temperatures although the daily differences in maximum-minimum temperatures were less than without a plastic covering. White translucent polyethylene film gave superior overall results in the Georgia, Illinois and Maryland tests. In overwinter tests in Illinois it also provided protection from erosion. Favorable soil moisture conditions were maintained when the surface soil was moist at the time of covering. These tests did not indicate an economic practicability for use of plastic coverings as stands and growth without the plastic were good, although significantly less than with the plastic.

At Bushland, Texas, grain and straw yields were approximately 20 percent better on subsurface than on one-way or field cultivator tilled summer fallow. At Mitchell, Nebraska, erodibility of plowed summer fallow for wheat was approximately two and one-half times that of subsurface tilled land, primarily due to reduction in residues. Subsurface sweep tillage gave a 35 percent reduction in residues, one-way tillage 62 percent and moldboard plowing 100 percent. The total cost of fallow operations

was $8.45 per acre on subsurface sweep tillage, $8.40 on one-way tilled and $11.60 on moldboard plowed summer fallow. At this same location sorghum residue reductions of 59, 66, and 100 percent were experienced with subtilled, one-way and plowed treatments. Runoff and soil loss from seeded wheat were 1.3 inches and 1,490 pounds per acre for subtilled land and 2.95 inches and 12,600 pounds per acre, respectively, for plowing. Runoff from fallow was less than 0.1 inch for subtilling and about 1.4 inches for plowing. Soil losses for these same two situations were 880 pounds and 6,700 pounds, respectively.

In other work at Mitchell, various sequences of tillage operation in combination with chemicals for weed control were studied. Relative weed control in June was considerably better for both broadleaf and grassy types where a spring tillage operation was included. Late summer or fall tillage gave no benefit in weed control. Evidence to date indicates that downy bromegrass sometimes fails to germinate until the second winter following production of seed and some type of tillage to assure its germination the first winter appears to be essential if mechanical control means are to be devised.

At Pullman, Washington, both runoff and soil loss were considerably reduced by incorporation of sweetclover, sweetclover-grass and wheat residues. Inclusion of grass enhanced reduction of runoff and erosion. At Cherokee, Oklahoma, runoff was observed to be less on continuous wheat than on alfalfa or weeping lovegrass. This behavior appears to be related to moisture condition and cover at the time rains occur.

At Big Spring, Texas, extreme difficulties in maintenance of sorghum residues in a cotton-sorghum sequence have been experienced. In general, residue levels are no more than 30 percent of the initial at cotton planting time and no more than 10 to 15 percent at harvest time. This has indicated a need for more permanent type vegetative cover in combination with cotton plantings to control wind erosion. Limited work with inter-planting of grass between cotton rows indicate successful establishment and adequate protection but considerably reduced yields due to competition from the grass.

In tillage studies related to erosion, residue reduction by various implements and sequences of operation indicate a greater residue reduction than previous work. For example, the subsurface sweep-type implement showed reductions of 30 to 50 percent of the initial residue compared to previous estimates of 10 to 20 percent. Disk-type implements show greater reduction with short stubble than with longer residues and the one-way disk, chisel cultivator and 32-inch sweep implement produced most soil cloddiness.

Plans: Existing studies of runoff and soil loss from different cropping systems and tillage practices under natural and simulated rainfall will be continued. Roadbank vegetation, grass water-way establishment and maintenance, gully control, terrace, and strip crop studies will also be continued. A new study of parallel terrace and strip crop design criteria

for Piedmont soils of the southern states will be initiated with headquarters at Watkinsville, Georgia.

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4. WIND EROSION CONTROL SWC

Problem: To develop criteria and practices to control soil erosion by wind and to adapt such practices to workable conservation farming and ranching systems.

Program: A continuing basic laboratory and field program is underway at Manhattan, Kansas in cooperation with the Kansas Agricultural Experiment Station. In addition, supporting field investigations on a continuing basis are conducted at Mandan, North Dakota; Akron, Colorado; Bushland and Big Spring, Texas; and in cooperation with State Experiment Stations in Montana, Nebraska and Idaho. The total effort is about 5 professional man-years annually.

Progress: In studies of the mechanics of wind erosion at Manhattan, Kansas, excellent simulation of wind reduction to the lea of windbreaks has been produced by systems of screens used in the wind tunnel. By dividing the simulated height into three segments and placing screens with differential porosity in each section, wind velocity to the lea of single-row evergreen, 10-row field and other windbreaks has been effectively simulated. This represents a major development in instrumentation for study of the effects of windbreaks and other barriers on aerodynamic phenomena.

In other studies at Manhattan, sorghum residue in a vertical position was found to be much more effective in wind erosion control than leaning or flat positions. Relative differences in erodibility were the same for the two soils of widely differing inherent erodibilities.

Measurement of wind profiles above various types of cover indicate that the height of zero wind velocity is imbedded below the top of growing crops or standing crop residues. For example, wheat stubble 33 cm. high gave zero wind velocity at a 10 cm. height, whereas sorghum stubble 71 cm. high gave zero wind velocity at 45 to 50 cm. from the ground surface.

In extensive studies of various mulching materials and other surface stabilizing treatments to control wind erosion during grass establishment, the use of a straight disk packer to anchor grass or straw mulch was found desirable. Prairie hay was found to be superior to equivalent quantities of wheat straw. Application of cutback or emulsified asphalt improved the stability of applied hay or straw mulches but were ineffective when applied alone. Smothering of grass seedlings occurred with prairie hay mulches of 4,000 pounds per acre or more where asphalt was applied unless the material was anchored with a packer.

Plans: Studies on this problem will continue at about the same level.

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VI. SOIL MANAGEMENT

1. FERTILITY REQUIREMENTS OF CONSERVATION FARMING SWC

Problem: Determine the amounts and balance of N, P, and K required in combination with other intensive management practices for the most efficient crop production and to study the efficiency of utilization of applied nutrients as affected by conservation farming.

Program: A continuing program of evaluation of methods of control of soil fertility in conservation farming in accordance with the requirements of the plant and environmental conditions carried on in cooperation with 23 states and involving about 31 professional man-years annually.

Progress: Heavy applications of ammonium and amide forms of nitrogen fertilizer increased soil acidity, not only in the surface but also in the deeper soil layers where correction by liming would be difficult. This effect was found to extend as deep as 30 inches in some soils after only three years of fertilization of both grasses and coffee with ammonium sulfate, for example. Ammonium nitrate and urea had an appreciable but less severe residual acidity. These results emphasize the importance of an adequate liming program in conjunction with intensive nitrogen fertilization to avoid serious soil acidity problems.

A major problem in grass fertilization is the inefficiency of grasses to recover and utilize a high percentage of the applied nitrogen fertilizer. Research on native range and introduced grasses is receiving increased attention in the Great Plains as the result of reduced acreages of some cultivated crops, increased demand for livestock feed, and conservation planning. Twenty-three years of data from North Platte, Nebraska, show that such soil bank practices as planting land to grasses and legumes, leaving the land idle, have little value in building up the soil but do reduce the rate of fertility depletion.

Results from field trials at several locations from the Canadian border to the High Plains of Texas show that, except in several drought years, grass yields, protein content and water use efficiency of native and introduced grasses can be increased by applications of nitrogen fertilizer. Response to nitrogen is, however, related to seasonal precipitation and temperatures and in many instances is often uneconomical. Effects of phosphorus, applied alone or in combination with nitrogen, on grass growth in the Great Plains are not consistent and are apparently related to the phosphorus supplying power of the soils of the experimental sites. At Mandan, North Dakota, phosphorus in combination with nitrogen has resulted in yields slightly greater than those obtained when nitrogen alone was applied. At Newell, South Dakota, significant growth response to phosphorus fertilizer by a mixture of bromegrass and crested wheatgrass was obtained only with high seasonal precipitation and when the quantity of phosphorus applied exceeded the soil phosphorus absorption capacity.

A major research program is underway to relate the nutrient requirements of dryland crops to the nutrient levels of the soil and the extremes of climate, especially precipitation. At Sidney, Montana, data from nine

experiments show that when soil test values were in the medium range (25 to 45 pounds P_2O_5 per acre), 81 percent of the variability in response to phosphorus fertilization could be accounted for by differences in available moisture at seeding plus precipitation during the tillering to heading period.

It appears that if Pullman and Amarillo soils which constitute a large portion of the southern Great Plains, are cut appreciably in land forming or leveling operations phosphorus fertilizer must be applied to obtain satisfactory yields. Similar results at Akron, Colorado, have shown that soils of the central Great Plains such as the Weld, Colby, Rago, and Keith also are low in phosphorus in some of their subsoil horizons.

A five-year study of off-season nitrogen application, which was completed in 1959, shows that the average efficiency of fall-applied nitrogen is entirely too low for this practice to be economically advisable in the Eastern and Southeastern United States. Nitrogen fertilizers, regardless of type, were less than half as effective on the average when applied in the fall as equivalent applications made in the spring. Corn yields and nitrogen uptake by the crop were used as criteria of effectiveness. The average percentage effectiveness at each of the eight locations were: Thorsby, Alabama, 69; Prattville, Alabama, 61; Watkinsville, Georgia, 48; Belle Mina, Alabama, 46; Brookville, Mississippi, 45; Poplarville, Mississippi, 45; Marcellus, New York, 32; and Tifton, Georgia, 13. These location differences were not related to total winter precipitation or average winter temperatures. Marcellus has the lowest winter temperatures and precipitation, but the apparent over-winter nitrogen loss was high. Nor were the differences clearly related to soil texture. Lower residual nitrogen effects were found on the medium to fine textured soils at Marcellus, Belle Mina and Brookville than on the coarser textured soils at Prattville and Thorsby. Further, the effectiveness of fall-applied nitrogen varied widely with years at a location, ranging from very low in some years to as high as that of spring-applied nitrogen in others. These differences on the same soils were not clearly related to yearly variations in rainfall, which suggests that volatilization may be as important a mode of nitrogen loss during the winter months as leaching.

Studies continued at Prosser, Washington, on the chemistry and availability of zinc (Zn) in irrigated soils. Acid-soluble (0.1 N HCl) Zn, interpreted in relation to lime content of the soil, has proven a good index for the adequacy of Zn for plant growth in soil samples from seven States. In 1953, Zn was applied to field plots at rates from 0 to 16 pounds per acre and the acid-soluble Zn determined annually. The original Ritzville fine sandy loam contained 2.1 ppm. HCl-soluble Zn and the annual values have fluctuated around this value. Where 4 pounds Zn per acre was added in 1953, acid-soluble Zn declined to the original value by 1956. Where 8 pounds Zn was used, the acid-soluble Zn reached a new equilibrium of 2.5 ppm. in 1957. With an initial 16-pound application the curve of decline of soluble Zn had not yet leveled off in 1959 and was at 3.2 ppm. Recommendations to farmers now call for the application of 10 pounds of Zn per acre each 5 years on Zn-deficient soils. This appears to be sound.

Research emphasis is now on the role of lime in relation to zinc availability and zinc solubility and on the nature of the compounds that form in soils that are non-extractable with acid and apparently unavailable to plants.

When no fertilizer nitrogen was used, the soil management system had a great effect on sugar beet yields and sugar production at Brawley, California, but when beets received adequate nitrogen, yields were the same regardless of previous soil management. The soil management systems for 1956 and 1957 were six, as follows: (1) alfalfa-alfalfa; (2) beets (no N)-barley (no-N); (3) beets (160 N)-barley (60 N); (4) beets (320 N)-barley (120 N); (5) same as (3) except sesbania was grown in the late summer; and (6) same as (3) except 10 tons manure were applied before each crop. Last cutting of alfalfa, and all beet and barley residues were removed from one-half of each plot. In 1958, beets were planted on all plots with six nitrogen rates varying from 0 to 420 pounds per acre. Without N fertilization, beets yielded from 17.8 to 28.2 tons per acre. The treatment ranks were $1>6>5>4>3>2$. Sugar yields ranked the same and varied from 4.85 to 3.17 tons per acre. With 420 pounds of nitrogen applied, beet yields and sugar produced were practically the same for all treatments. Beet yields ranged from 32.0 to 33.7 tons per acre, and sugar yields from 5.17 to 5.53 tons per acre. Residue removal or retention produced no significant effects. Water infiltration rates measured with double rings before beets were planted were higher on plots that had been in alfalfa or sesbania or got manure, but higher infiltration had no effect on yields if nitrogen was adequate. The conclusion is that alfalfa, sesbania and manure were beneficial because they supplied nitrogen and their effects on soil physical properties were of no significance on the Holtville silty clay loam.

In the last 5 years, considerable attention has been paid to the recovery by crops of fertilizer nitrogen applied to irrigated soils under conditions of irrigation and drainage such that leaching losses were absent or greatly minimized. At Brawley, California, in 1955, an experiment was started with five inorganic nitrogen sources and alfalfa meal. Four rates of application of nitrogen from these sources were made to cotton followed by barley each winter and grain sorghum each succeeding summer. One set of plots has never received fertilizer. Through the summer of 1958 plots at the highest rates of nitrogen application had received a total of 1300 pounds of nitrogen per acre. A careful inventory of all nitrogen removed from the plots in cotton bolls, barley and sorghum grain has been kept. In 1958 the sorghum was removed as silage. All other crop residues have been left on the plots. In general, the inorganic nitrogen carriers (Calcium nitrate, ammonium nitrate, ammonium sulfate, urea and aqua ammonia) have produced equal yields and nitrogen recovery. Alfalfa meal has performed less well because of its carbon content. In the seven crops, total nitrogen removed from the unfertilized plots was 124 pounds per acre. Where 1300 pounds of nitrogen were applied from inorganic sources, the total nitrogen removed averaged 484 pounds per acre. Assuming that nitrogen application did not affect mineralization of nitrogen in the soil, the recovery of nitrogen amounted to 27.7 percent of that applied. Where the rate of nitrogen application was far below commercial practice (325 pounds per acre for the seven crops), the recovery was

204 pounds. Subtracting the check gives a percentage recovery of fertilizer nitrogen of only 24.6 percent. The plots were fallowed during the 1958-59 winter and planted to unfertilized Sudan grass in 1960. It contained in its total tops 14.2 pounds where no nitrogen was used and 28.9 pounds per acre where 1300 pounds had been applied to the sequence.

This recovery of 14.7 pounds represents only about 1.6 percent of the 940 pounds presumably left in the soil. Cotton will be grown in 1960 to get more of the residual nitrogen. Changes in soil nitrogen and organic matter have not yet been evaluated, but all data now indicate that nitrogen recovery on Holtville silt loam, a high calcareous soil, is very low.

Similar studies have been conducted on recovery of fertilizer nitrogen applied to western wheatgrass on the clay soils of the Milk River Valley in Montana. Applications of nitrogen from none to 400 pounds per acre were made in 1955 only and the effects on grass yield and nitrogen removed measured for the 4-year period 1955-58 when all the residual nitrogen had been removed. On plots properly irrigated (when 75 percent of available water remained in the top foot of soil) the total hay yields for the 4-year period were increased from 2.2 tons per acre without fertilizer to 5.2 tons where 400 pounds of nitrogen was applied in 1955. On plots irrigated according to custom in the valley which is continuous spring flooding only, the yields were 2.95 and 3.7 tons per acre, respectively. On plots irrigated properly, 35 percent of the 100-pound rate of nitrogen application was recovered in the hay and 19.6 percent of the 400-pound rate was recovered. On spring-flooded plots, nitrogen recovery was much lower, being 4.3 and 7.0 percent, respectively. Highest hay yields were obtained with annual applications of nitrogen. Putting on 400 pounds of nitrogen annually increased total acre yields for the 4-year period from 2.08 tons to 11.4 tons on the properly irrigated plots. The experiments were stopped before all residual nitrogen could be cropped out on the annually-fertilized plots, but the available data indicates the nitrogen recovery was even poorer.

Evidence of much higher rates of nitrogen recovery is, however, available. Many experiments on recovery of nitrogen by annual crops show 50 to 60 percent recovery in the crop the season of application. Other experiments on exhaustive cropping until all residual nitrogen is removed show good recovery of fertilizer nitrogen. In a pot experiment involving 14 soils varying from loamy sand to Pierre clay in which aeration could be vastly different, the recovery of nitrogen by bromegrass averaged about 77 percent and was similar for all rates of application. Recovery from silt loams and clays was slightly lower than from the other soils. In a 6-year field study at Prosser, Washington, in which the first four crops (sorghum, beets, potatoes, sorghum) were fertilized with each of three nitrogen carriers up to rates of 160 pounds of nitrogen annually and then two crops of corn were grown without nitrogen fertilization, the average nitrogen recovery was 82.9 percent of that applied. Overall, recovery was the same for all sources. Percentage recovery was greater the higher the rate of application. These experiments on nitrogen recovery involve the assumptions that nitrogen content of the soil does not change, which may not be true, but they do show the efficiency of nitrogen use for all

practical purposes.

Reducing the water-soluble P content of mixed fertilizer through increased levels of ammoniation decreased its availability to crops, although the availability indicated by the current standard of citrate solubility was not affected. Regional studies carried out in South Carolina, New York, Alabama, and Mississippi showed generally reduced growth of oats, wheat and millet as the percentage of water-soluble phosphorus was decreased from 85 to 14 through variations in degree of ammoniation. However, when the same range in water solubility was tested in a control fertilizer composed of mixtures of di-calcium and monoammonium phosphates with ammonium nitrate, there was little or no difference in plant availability. These results show that mixed fertilizers with constant citrate-soluble phosphorus fractions have marked differences in plant availability of the water-insoluble fraction, depending upon the method of preparation. They further show that phosphorus availability is definitely reduced by excessive ammoniation in the current trend toward higher ammoniation of mixed fertilizers and point to the need for characterization of plant available phosphorus of mixed fertilizers beyond their citrate and water solubility.

A longer lasting effect has frequently been claimed for raw rock phosphate than for more readily available materials such as superphosphate, although experimental evidence is entirely inadequate to support this idea. An integral part of the plan of a regional rock phosphate evaluation study begun in 1952 was to measure the relative residual effects of rock- and superphosphate at the end of the period of fertilization. This was done in a greenhouse study at Auburn, Alabama, with 11 soils from field experiments in six Southeastern states. Using the uptake of phosphorus by white clover as a measure of residual phosphorus availability, the following facts were established: In 9 of the soils superphosphate, applied in five annual increments of 60 or 120 pounds P_2O_5, had a greater residual effect in the sixth year than equivalent amounts of rock phosphate in a single initial application. Its effect was less in only one soil. Furthermore, superphosphate in annual increments of 60 pounds P_2O_5 also had as high or higher residual availability as a single application of rock phosphate at twice the cumulative rate of superphosphate in 9 of the soils. Where both sources had been used in single applications, with rock phosphate at twice the equivalent rate of superphosphate, the residual effect of the superphosphate was as great or greater than that of rock in eight of the 9 soils for which this comparison could be made. These results clearly show that rock phosphate does not have as high a residual value on most Southeastern soils as superphosphate, even when used at much higher rates.

Plans: Major emphasis will be placed on the interactions of nutrient levels, moisture regime and genetic constitution of the plants. Additional emphasis will be placed on the relationships of fertilizer use and application requirements in relation to moisture supply for crop and range plants, and on nitrogen, phosphorus and minor elements to improve and maintain crop quality and efficiency of production.

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2. CROP RESIDUES, TILLAGE AND MOISTURE CONSERVATION SWC-AE

Problem: Evaluate effects of mulches, tillage, crop residues, and soil physical conditions on the conservation of soil and water resources and plant growth.

Program: A continuing program of research in 19 states, cooperative with State agricultural experiment stations and involving about 17 professional Federal man-years annually.

Progress: In Iowa, 5 different tillage methods: plowing, wheeltrack planting, mulch tillage, ridge planting, and listing are being evaluated at 6 locations in the state. No single tillage treatment is best for all conditions, yet, in general, it seems difficult to find a treatment that will give high yields as consistently as the conventional plowing. Wheeltrack planting also has been good, although if the soil is dry at planting, stands may not be as good. Listing has been outstanding on the Moody silt loam in northwest Iowa where soil moisture often is a serious limiting factor. Ridge planting and mulch tillage have also been well above average in this area. Mulch tillage has been poor where the soil is cold and wet in the spring.

On highly erodable soil at Holly Springs, Mississippi minimum tillage, mulch tillage, and conventional tillage were about equally effective for corn production last year, a year of generally favorable soil moisture.

At Marcellus, New York, plowing and planting in the same operation frequently gives poorer stands, poorer early growth, and lower yields of corn. Although part of the trouble may be associated with a poor seedbed, it appears that other factors may also be involved. The poor stands associated with plow-plant have been more evident when the date of corn planting is delayed beyond normal planting time. Apparently this is because the soil is more likely to be a little too dry for good seedbed preparation with existing plow-plant equipment.

Another problem with wheeltrack planting showed up last year on fieldsize plots in Wisconsin. On one farm planted 5 percent off the contour, the wheeltrack concentrated runoff until overtopping occurred. Observations on another farm with hummocky topography, indicate that less gullying occurred when planting was either on the contour or directly up and down

the slope than when planted on a 4 to 5 percent grade.

Soil properties and climatic factors greatly affect the responses of corn plants to crop residue mulches. The effect of a straw mulch (as compared with straw plowed under) on soil moisture, soil temperature, early plant growth, nutrient uptake, and yield of corn was determined at 8 locations (Minnesota, Iowa, Wisconsin, New York, Maryland, Virginia, South Carolina, and Georgia) representing extremes of soil and climate in the eastern half of the country. Simazine was used for weed control and the soil was not cultivated following corn planting. The mulch lowered soil temperature, and in some experiments markedly decreased early growth. In general, depression in early growth under the mulch has occurred only in the northern states, but last year there were notable exceptions. Thus, at LaCrosse, Wisconsin the soil was unusually warm at corn planting time and no injury was noted. But at Watkinsville, Georgia, corn was planted earlier than usual and early growth was depressed by the mulch. Soil moisture early in the spring was higher under the mulch, and at locations where soil moisture was already high, may have contributed to the poorer growth under the mulch. Yet, at Marcellus, New York, soil moisture was no higher under the straw mulch than under black plastic, and there was no depression of growth on plots covered with the plastic.

In general, plants on the straw mulch plots recovered and yields of grain ranged from slightly poorer to significantly better than on the controls. In Minnesota for example, although the mulch decreased total weight per plant by 50 percent early in the season, the yield of grain was increased by 12 bushels per acre. This increase in yield was associated with a higher soil moisture late in the season. At LaCrosse, Wisconsin, where the soil was warm at corn planting time and soil moisture adequate throughout the season, the mulch had no apparent effect on either early growth or yield or grain.

A water soluble substance that depresses germination or growth of roots or tops of corn may often be present in soil from stubble-mulched fields. A methyl alcohol extract of soil from plots where stubble mulching had been practiced for several years contained organic materials as yet unidentified which depressed oxygen uptake of wheat seedlings. It is entirely possible that the presence of toxic organic compounds in soils where stubble mulching has been used may account for yield depression sometimes encountered with this form of surface residue management. Some of the fungi isolated from stubble-mulch plots produced substances in the laboratory which depressed germination of growth of tops or roots of corn.

Plans: Work will be continued at about the same level with emphasis on developing effective practices to utilize more efficiently the benefits of soil crops on the growth of the subsequent row crops. Studies will be continued on methods and equipment needed for preparing seedbeds chemically and mechanically, on the effect of tillage equipment in systems, on emergence rates, rate of growth, nutrient up-take, stands, and yield of corn on various soil types.

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3. TILLAGE EQUIPMENT SWC - AE

Problem: Determine the factors applicable to tillage implement design and to the design of tractive devices, such as tires and tracks, including equipment for erosion control and problems of effects of traffic on agricultural soils.

Program: A continuing program involving basic and applied soil-implement relationship studies with headquarters at the National Tillage Machinery Laboratory, Auburn, Alabama, in cooperation with State Agricultural Experiment Stations of Alabama, Georgia, Iowa, and Michigan and also with farm equipment manufacturers, involving about eight professional Federal man-years annually.

Progress: Soil Dynamics. The reaction of soil to mild steel and plastic coated straight tines was studied at various angles using sand, a sandy loam, and a clay soil. The work was done in a glass sided model box and a high speed movie was prepared of the soil reactions. Soil-metal and soil-plastic friction-adhesion measures at several normal loads were measured. Measurements were made of soil forces on two-inch wide straight tines at five rake angles in a sand, sandy loam, and clay operating at 2-, 4-, and 6-inch depths. Stress-strain measurements were made on briquettes of a kaolinitic and a montmorillonitic soil loaded in tension. Exploratory measurements were made of the acceleration forces in soil resulting from plowing with a 14-inch moldboard plow operating 7 inches deep and at 5 to 10 mph. Maximum accelerations up to 12.8 g's were measured. A test was started in cooperation with the Georgia Agricultural Experiment Station to determine the effect of preceding crops and depth of tillage on peanut production. A Teflon covered moldboard plow was found to do a good turning job on a sticky low cohesive soil (Davidson clay) with 23% less draft than was required for a steel plow that did a poor job of turning the soil. This was the first time this soil had been turned satisfactorily with a moldboard plow since it was placed in the test bin 25 years ago.

Laboratory studies using model disks and small soil bins on tracks were continued. The prediction of forces using the similitude theory was improved by using soil shear as one of the soil factors. Additional accuracy was obtained by refining the method of obtaining uniform soil moisture and compaction. In addition, determining the distortion factors that were included in the functional equation improved the prediction accuracy.

Disk Blade Studies. The basic studies of soil reactions to disk blades were continued in two soils. Results from tests made in the Lakeland sand and Hiwassee sandy loam soils bins using the same disks as previously reported indicate that the angle at which the disk is set and the width of the furrow slice are important factors in determining the weight required to achieve the desired penetration, as well as the magnitude and direction of the lateral force acting on the disk. In some soil conditions these disk settings also appreciably affect the draft, while the effect of other soil conditions on the draft is not so great. When

the data from tests made in the two soils are compared, it is generally found that the forces acting on disks can be plotted as a series of curves for different soil conditions and disk designs. Data from comparative tests of two disks, having the same dimensions but different edge bevel designs, indicate that those disks having the bevel on the face side of the edge require less weight to cause penetration to the same depth than disks having the conventional edge design.

Subsurface Tillage. Studies of design factors for subsurface tillage implements were continued to determine the relationship of forces applied to soil reaction. Equipment was developed to obtain good pulverization of soil in a trench approximately 16 inches wide and 18 inches deep with the loose soil in a mound over the row area. The unit tills two rows and in Lloyd clay loam left mean clod size diameter of approximately 1/8 inch. The wheels of the tractor operate on firm undisturbed soil.

Tires and Tracks for Traffic and Traction. The determination and evaluation of the effects of various designs and methods of use of tractor tires and crawler tracks on their performance and efficiency under various soil conditions was continued. It was found that adding a belt of fabric over the conventional carcass improved the performance of the tractor tire but did not make it as effective as a radial ply tire. Reducing the angle of the ply cords of a tire from 40 to 30 degrees reduced its effective performance. The differences in tractive effectiveness between the radial ply and a conventional ply tire were not affected by changing from air to water filling. The traction performance of an experimental belted military type tire was up to twice that of a regular production tire. On loose sand, the belted tire at on-the-road inflation (30 psi) had the same tractive performance as a regular tire at 20 psi. Tests were made using six experimental tires, three with lugs and three with the lugs ground off, having the following construction variations: (1) regular profile - regular cord angle, (2) regular profile - radial cord angle, and (3) flatter tread base radius - radial cord angle. The radial ply tires outperformed the conventional ply tires under all conditions. The advantage for the lugged tires was greater than for the smooth tires. Field tests made as a part of the continuation of the study to determine the most suitable equipment for use on self-propelled high clearance spray units showed that the use of larger tires, low pressures, and experimental wire scrapers improved operation but still were not effective under extreme field conditions. A steel rim wheel with lugs did the best of any arrangement tried. Search for a tire coating material which will shed mud was continued. A method of applying Teflon to the area between lugs has been discussed and will be tried.

Effect of Tillage and Traffic on Soil Physical Conditions. Studies of the soil physical conditions in a long time cover crop experiment in western Alabama were continued. The work was done in cooperation with the Agronomy and Soils Department, Auburn University. The effects of deep tillage performed in October 1958 were detected in terms of bulk density and resistance to penetration differences during the 1959 growing season. The effect of the deep tillage was decreased to a large extent by subsequent field operations so that root impedance was present. Studies

were initiated to determine methods by which the amount of work done by tillage implements to the soil could be measured and expressed. At the present time evaluation of implement performance is based on a subjective visual performance or on power input to the implement. The consideration of work done on the soil system in a thermodynamic sense would require that the various physical phases which consume energy would have to be isolated and evaluated. Tentative phases of work isolated for consideration and evaluation include: gravitational potential, acceleration of soil, compaction of soil, shearing of soil, friction loss and abrasion loss. Within the framework of such a consideration exploratory experiments have indicated that a number of the factors can be satisfactorily investigated. The size of cut of a simple tillage tool was found to influence the size of soil clods and the efficiency of implement operation. A method was developed to estimate the work required to pulverize the soil. Blocks of soil were dropped on a rigid surface and the relationship between the potential energy input (mgh) and the resultant shattered clod size was determined. This relationship was used to evaluate the effective work done by two simple tool shapes on a hard soil.

Methods and Equipment for Measuring Force Distribution in Soil. During the past year standard triaxial apparatus was modified so that three dimensional stresses, three dimensional strains and volume strain are simultaneously measured and recorded under carefully controlled loadings. Techniques for manipulating the soil have also been developed so that loose but uniform soil samples can be prepared, placed in the apparatus, and removed after testing. Enough measurements have been made to show that the apparatus can be successfully used to measure applied forces and resulting deformations in arable soils.

Statistical Techniques and Methods. Research has been conducted by contract with the Statistical Laboratory at Iowa State University on statistical methods for analysis and interpretation of data on similar but not identical experiments which are often used with tillage machinery.

Plans: Studies will be continued on the similitude of scale model tools to full scale tools, soil stress-strain relationships, methods of measuring soil strength, wear resistance of materials, friction adhesion measurements, and of materials and soil reaction to disk blades. Study of design and operational factors of tires and tracks which improve traction and flotation will be continued. Studies will be initiated to determine the value of using soil shear measurements to describe the physical condition needed for seedbeds.

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4. MANAGEMENT OF SALINE AND ALKALI LANDS SWC

Problem: Water table height and water quality in relation to sodium and salt accumulation, and the effect of water quality, amendments and leaching on the salt status of the soil and plant growth, must be investigated to enable intelligent management of saline and alkaline crop lands and irrigation water.

Program: A continuing program of research in nine States, in cooperation with State experiment stations, and in some with the Bureau of Reclamation, the Corps of Engineers, and the Soil Conservation Service, involving about seven Federal professional man-years annually.

Progress: Reclamation of sodic (alkali) soils is a problem which has received world-wide attention. A method for reclaiming sodic soils, based upon well-founded theoretical principles has been proposed at the Salinity Laboratory, Riverside, California. Both from theory and from experimental studies, it has been shown that sodic soils can be reclaimed by the use of sea water or other high-salt waters of similar composition. By diluting sea water with irrigation water and leaching the soil, either in successive dilution steps or on a continuous dilution basis, the exchangeable sodium of the soil is reduced. Studies show that sodic soils can be reclaimed much faster by using sea or other high salt waters in the initial stages of leaching. By using successive dilutions of Salton Sea water with Colorado River water the exchangeable sodium percentage of a column of sandy soil was reduced from 39 to about 5 in one-tenth the time required with Colorado River water alone. Hydraulic conductivity of the soil is much higher when high salt water is used. Total water required for leaching is higher when high salt water is used initially and gradually diluted with low salt water, but its extra cost may be more than compensated by the great reduction in time required for reclamation. Field studies are to be started. The long time now required for leaching sodium from soils because of their low permeability is now a major deterrent to their reclamation.

The method involved is a direct result of basic research on cation-exchange equilibria and water movement in soils as influenced by adsorbed cations and salt concentration of the water. An empirical relationship known as the "Sodium-adsorption-ratio" serves as a convenient and useful means of

making application of this principle. Also involved is the principle relating to the effect of electrolyte concentration of the water on the permeability of the soil. The high electrolyte concentration of the sea water has a flocculating effect on the soil which increases the soil permeability many-fold and hence materially shortens the time required for reclamation. In addition, upon dilution, the divalent cations (calcium and magnesium) from the sea water are made available for exchange with the sodium that is absorbed on the soil, even though the sodium salts constitute more than 75 percent of the total in sea water. Thus, a high-salt water not only speeds up the reclamation process, but also is a source of divalent cations for replacement of exchangeable sodium. Laboratory results have shown a 30-fold increase in the rate at which a soil transmitted water where successive dilutions of sea water were applied. Of considerable practical significance is the fact that, of the total amount of water used in reclaiming the experimental soil columns, 95 percent was irrigation water. In other words, only a relatively small amount of sea water is required to accomplish the reclamation. Other high-salt waters such as well waters, drainage waters, sea-water conversion wastes, and other waste effluents may be used also. Moreover, it is not the water per se that is important but the salt contained therein. From this, it is evident that it may be possible to use salts as additives to irrigation waters for reclamation purposes.

In making application of this method for field conditions, the use of low-cost mixed salts from any of a number of sources as an additive in irrigation waters should be investigated. Also to be studied are the optimum salt concentrations and the rates at which the concentrations can be reduced as related to soil properties and other influencing factors. It is envisioned that both laboratory and field studies can be used effectively in working out practical applications in the field.

Field studies over an 8-year period on the Shadehill Development Farm at Lemmon, South Dakota, have shown that the exchangeable sodium percent (ESP) in the soil has not reached the values expected from the sodium absorption ratio of the reservoir water used. Furthermore, the residual sodium carbonate in the water did not increase the sodium content of the soil. The ESP had reached 10 percent and the infiltration rate and structure of the soil remained good. Further field studies were conducted during the year in which the soils were leached with poorer qualities of water made by additions of $NaHCO_3$ to determine at what values of ESP soil structure deteriorated. The U. S. Bureau of Reclamation was interested in what would happen if the reservoir water became of very poor quality and then whether the sodium on the soil could be removed by leaching. Values of ESP as high as 20 were attained. Subsequent leaching with water varying from stock pond water to Shadehill reservoir water showed that some of the sodium could be replaced, but that leaching with water slightly lower in quality than the present Shadehill reservoir water would require addition of gypsum to displace the sodium. The highest levels of ESP attained (about 20 percent) caused poor structure in the surface soil and some decline in the infiltration rate. However, the lowest infiltration date was still satisfactory for crop production. Lower values of ESP had no significant effects on structure or infiltration rates.

Studies on gypsum treatment and gypsum in combination with deep chiseling and deep profile mixing were continued on "slick spots" of the Black Canyon project in Idaho. "Slick spots" are high in salts and exchangeable sodium, produce little or no crop and take in water extremely slowly. Salts and exchangeable sodium in the 24-inch depth have been reduced to tolerable levels on all treated plots. Intake rates have been increased from 0.01 inch per hour on the untreated areas to 0.6 inch per hour on the gypsum-only plots. On the deep-mixed plus gypsum plots, intake rates were increased to over 2.0 inches per hour. Production of alfalfa-grass hay was only 1.2 tons per acre for the untreated plots and from 8.24 to 9.48 for the variously treated plots. Large field-scale treatments have been initiated to see whether these findings can be applied to solve this serious problem on southern Idaho and eastern Oregon irrigated lands.

At Weslaco, Texas, an evaluation of a newly-installed drainage system on a highly saline Hildago clay loam showed a removal of 40 tons of salt per acre from April 1958 to April 1959 determined by soil sampling and 29.5 tons per acre determined by measuring amount and salt content of drain effluent. If the assumption is made that water passing downward had the same salt content as the drain effluent, then calculations show that 2.6 inches of water was not intercepted by the tile. One foot of irrigation water was used and 30 inches of rain fell during the test period.

The effect of land use on salt content of soils and the effect of salts on tree survival in shelterbelts (cooperative with CR) was studied near Grand Forks, North Dakota, over a saline water table. On land that had been in grass in the shelterbelt for 23 years, the surface soil was nonsaline (ECs 3.5 mmhos. per cm.). On adjacent land cropped continuously to wheat the surface soil was saline (ECs 8 to 9 mmhos. per cm.). Part of the differences is probably due to land use; part is due to the extra water for infiltration from snow interception by the trees. Russian olive was found to be most tolerant to soil salinity followed by Siberian elm. Green ash, boxelder and cottonwood had failed to survive where the original salinity was estimated to be in excess of 8 to 9 mmhos. per cm. Soil salinity was not a big factor in depth of tree root penetration. Most of the roots were in the upper 2 feet of soil in all cases.

Water resources along the coast have, in many cases, been reduced in quality to an unusable level by contamination with sea water. Such contamination may result from inundation of surface water resources during hurricanes, seepage through dams or other water retaining structures, or from salt water intrusion into underground aquifers. Brackish water studies have dealt with an evaluation of the extent of water resource contamination and with the consequences of use of contaminated water for irrigation.

Under normal rainfall in 1959, there was a steady decrease in salt concentration in most of the brackish water ponds examined in New Jersey, Virginia, North Carolina, and South Carolina. Ponds which were inundated by high tides were usually flushed of the high salt concentration in six months.

In Virginia, field plots were brought to various levels of salinity by irrigation with diluted sea water. After salinization, the plots were sampled at periodic intervals to determine the movement of the added salt. By the end of February, the greater part of the salt had been leached out by natural rainfall. By spring planting time, the salt content of the soil was sufficiently low to be safe for planting most crops.

Salt movement through soil was also evaluated in a lysimeter in Virginia. Of the 43 inches of water added as rainfall or irrigation, only 4 inches were removed as effluent between May 7 and November 21. Of the salt that had been added on May 7, 63 percent remained in the profile on November 21. Leaching of chloride from the soil profile was influenced by amount and distribution of rainfall and antecedent soil moisture content.

Equations which describe cation-exchange equilibria in soils are of extreme importance in salinity investigations because they permit estimation of the composition of the adsorbed cations from the composition of the dissolved cations, and they aid in predicting the effects of irrigation waters on the exchangeable-sodium-percentage of soils. Previous work has resulted in a satisfactory equation for neutral and alkaline soils having a predominance of permanent negative charges on the particles. Unsatisfactory results are obtained, however, when this equation is applied to acid soils having larger amounts of positive and pH-dependent negative charges on the particles. Work is under way to clarify reasons why the equation fails with the latter soils; and, if possible, to modify the present equation or develop another equation for these soils. The data at hand indicate that the problem is exceedingly complex.

Plans: This work will be continued at approximately the same level. As new concepts and techniques are developed, they will be tested over a range of problem areas in key locations.

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5. RANGELAND SOIL MANAGEMENT SWC

Problem: Rangeland soil resources are being damaged by erosion. Range production suffers from poor knowledge of how to combine fertility, moisture conservation, and forage management practices on many soils.

Program: A continuing program dealing with rangeland practices related to erosion, moisture conservation and fertility, methods for improving species composition, and establishment of new seedings, under way in Wyoming, South Dakota, North Dakota, Texas, and California in cooperation with State Experiment Stations and involves about two professional Federal man-years annually.

Progress: Continued work at Laramie, Wyoming, on assessment of effects of cover on infiltration on rangelands indicate that from 60 to 85 percent of variation in intake is accounted for by standing vegetation and mulch on the soil surface. On both sandy and silty soils, standing vegetation has a major influence, but on silty soil effects of mulch on the surface are not of consequence.

At Laramie, Wyoming, lamb gains were 13 to 16 pounds per acre greater on range-seeded plots than on pitted or sod-drill-treated areas. Crested wheatgrass still remains in the range-seeded pastures but seeded alfalfa has largely gone out. Studies utilizing supplemental pastures of oats, sweetclover and Sudan grass gave 232 sheep days per acre grazing capacity and 112 pounds lamb gain per acre during the interval June 30 to August 26. Both lamb gains and duration of pasturage was approximately equal for oats and Sudan but considerably lower for sweetclover.

At Bushland, Texas, nonfertilized blue grama grass responded very little to variable initial soil moisture conditions. However, where adequate moisture was maintained and differential fertilizer rates applied, large yield increases were obtained. Neither yield levels nor water-use efficiency on blue grama grass compared favorably with that of Sudan grass for the same approximate time interval. With adequate nitrogen, Sudan grass produced approximately 5 tons per acre of dry matter with a water use of approximately 25 inches compared to 3 tons per acre and 43 inches of water for blue grama grass at the same nitrogen level. At Riverside, California, fertilization of native annual range with 84 pounds per acre of nitrogen resulted in a 50 percent increase in both carrying capacity and pounds of animal gain per acre. A grazing income of $3 per acre was registered but a net loss of $7.50 per acre accrued when compared with nonfertilized area. This is in contrast to 1958 results in which a net profit was obtained

due to fertilization. These results are not surprising in view of the fact the 1959 season was one of the driest on record in this area.

At Newell, South Dakota, moisture use efficiency was increased 60 percent by fertilization of native range on dryland and was doubled where supplemental water from a water spreading system was available.

At Manhattan, Kansas, damage due to sandblasting of various plant seedlings reduced yields from 18 to 55 percent. Of the six species studied, side-oats grama grass appeared to be least sensitive and alfalfa most sensitive to such seedling damage.

Plans: Emphasis will continue on evaluation of practices to improve cover and production relationships and to successfully establish better vegetation, especially on severe hazard areas.

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6. RADIOACTIVE FALLOUT SWC

Problem: To determine the accumulation and movement of fission products, particularly strontium 90, in soils and plants, particularly to delineate the adsorption reactions of strontium and calcium with clay minerals; to study the possibility and magnitude of non-exchangeable fixation of fall-out strontium 90 by natural soil components; to decrease the uptake of strontium 90 by crops by applying various soil amendments and tillage practices; and to determine the loss of fallout strontium 90 from erosion experiment plots.

Program: A continuing program carried on at Beltsville, Maryland and several field stations under contract from the Atomic Energy Commission and involving seven professional man-years annually.

Progress: Four methods of forage harvesting were used to remove simulated dry fallout from land with a cover of soybeans. The four methods, (1) mow, windrow, and bale, (2) mow, windrow, and chop, (3) direct cut chop, and (4) flail-type chop, all appeared to remove about half of the contamination, although experimental difficulties prevented exact determinations of the amount removed. The soybeans were 12 to 16 inches tall and covered an average of 75% of the soil surface when viewed from directly overhead. There was a significant correlation between percentages of ground cover and decontamination.

Scraping off two inches of soil with a bulldozer or road scraper gave 80 to 100 percent decontamination of bare soil from simulated dry fallout. Scraping off about 7 inches of soil with an eight cubic yard scraper gave 99 to 100 percent decontamination on either seedbed or plowed land. The other scraping implements usually gave better decontamination on seedbed than on plowed land.

Strontium is adsorbed on clay minerals by a cation exchange reaction which follows the chemical law of mass action. For the principal part of the exchange reaction when strontium replaces calcium, the equilibrium constant is 1.0 on kaolin, 1.1 on illite, and 1.4 on bentonite. This means that strontium and calcium are held equally tightly on kaolin, and strontium is held a little more tightly than calcium on illite and bentonite. For a small part of the exchange reaction, about one percent on kaolin and bentonite, and five percent on illite, strontium is held much more tightly than calcium, with equilibrium constants of the order of 25. The equilibrium constants do not change upon varying the pH of the clay suspension from 4 to 9. The exchange capacity for kaolin and illite approximately doubles when the pH is increased from 4 to 9, while that for bentonite increases about 25% over the same pH range.

Laboratory studies showed that one week after adding soluble carrier-free strontium-89 to 12 varied soil types, 1 to 20% was fixed; that is, it was not readily extracted by exchange with a neutral salt solution. The percentage of strontium fixed was higher when they were kept at 60° C. than at room temperature, and was higher when they were alternately wetted and dried than if they were kept continuously moist. The percentage of strontium fixed under given conditions was characteristic of each soil.

More strontium-89 was translocated from applications to bean leaves when the treated leaves were kept wet. About 0.1% of the application was translocated to other parts of the plant in four days from wet leaves, and about 0.4% from leaves allowed to dry. Glucose or boric acid in the solutions applied to treated leaves had no measurable effect on translocation.

Plans: Work will continue to devise more accurate means for ascertaining contamination, and methods for removing and managing contaminated surface soil; to further characterize exchange reactions and surfaces responsible for strontium fixation in various soils, and to delineate the translocation of strontium 90 from leaves to edible and other parts of plants at different stages of growth.

Publications: Removal of Simulated Fallout from Farm Land. Paul E. James and Ronald G. Menzel. Plant Food Rev. 5(2): 5-7. 1959.

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Effects of Amendments on Availability. R. G. Menzel. Proc. Univ. of Minn. Symposium "Radioisotopes in the Biosphere". 37-46. 1960.

Nature and Effects of Radioactive Fallout on the Farm. R. F. Reitemeier. Jour. Amer. Vet. Med. Assoc. 136(8): 394-397. April 15, 1960.

7. AGGREGATE EFFECTS OF IMPROVED SOIL MANAGEMENT FE

Problem: Specific and aggregate effects of changes in farm technology on farm output need economic analysis if we are to suggest adjustments between the land base and levels of technology that would be most profitable in meeting output needs, in view of opportunities created by new developments that influence crop yields.

Program: A continuing program to: (1) appraise the effects of crop yield influencing factors and the impact of changes in yields on shifts in crop production through which different levels of output could be produced most economically on farms and in important soil and type of farming areas; and (2) to analyze results of controlled experiments and of technicians estimates of yield response to changing technology applicable to specified levels of management on farms, and to interpret results in terms of decisions farmers must make within the framework of various capital, organizational and institutional patterns. Work is in cooperation with State experiment stations and other agencies of the Department, and currently involves about 3 man-years annually.

Progress: Effects of Changes in Farm Technology in the Georgia-Piedmont. In a pilot study in the Georgia-Piedmont to determine the feasibility of obtaining and using technicians' estimates as a major basis for relevant input-output information applicable to areas, estimates of yield response to fertilizer at present levels of management, have been obtained for each crop occurring in 17 different rotations. These estimates were developed for Cecil and related soils of land capability Class II and

conversion factors were suggested to establish the yield response pattern for other soil groups and capability classes. A second set of estimates is now being developed to indicate probable response assuming potential levels of management. In this, the "bundle" representing potential management is being defined so that costs and returns can be estimated over a range in levels of soil and crop technology.

Data from the recently completed nation-wide survey of conservation needs are now available for the Georgia-Piedmont and are being used in the study. These data show by major land uses, the acreage in each soil group and capability class for which estimates of yield response are being developed.

The major objective of the study, which is macro-analysis, or aggregate effects of changes in technology, is necessarily preceded by a "micro" phase in which physical input-output relationships are established. Some of the results of this phase can now be indicated. They relate to the effect of changes in fertilizer use on yields under present management on farms in the area. As an example of this, at rates of fertilization to result in maximum profit per acre, the return above fertilizer cost per rotation acre in a 3 year rotation of corn with Coastal bermuda is nearly three times as great as in a 3 year rotation with fescue.

In the corn-coastal bermuda rotation on Cecil and similar soils, returns above fertilizer cost per rotation acre would be about $68.00 for class II land, $48.00 for class III, and $29.00 for class IV. Class I land comprises only 5/100 of one percent of all land in the area.

Data indicating similar comparative results for all crops as used in all rotations considered feasible, are being developed and put in form for use as guides to farm planning. This is being done both for present and for potential management levels.

Effect of Changes in Farm Technology on Cropping Systems in Highly Productive and Less Productive Areas in Illinois. In the cash grain area of east-central Illinois, as more fertilizer was used compared with 1954, the optimum cropping system shifted from use of two-thirds of the land in a corn-soybean-wheat rotation, and one-third corn-corn-soybeans, to one with 55 percent in the corn-corn-soybean rotation and 45 percent in a corn-soybeans-oats sequence. This represents an increase of about 7 percent in the acreage of corn and a corresponding reduction in the acreage of small grain. The acreage of soybeans would remain substantially unchanged.

In the clay pan area of south-central Illinois, the optimum rotation would involve a general shift from small grain to soybeans and a more intensive cropping pattern with increased use of fertilizer. The basic shift would be from a system with about 90 percent of the land in a corn-corn-soybeans-wheat (clover) rotation and 10 percent continuous soybeans, to one with 55 percent of the land in continuous corn and 45 percent in continuous soybeans. This represents an overall increase of 10 percent in the acreage of corn and 14 percent in the acreage of soybeans, with elimination of small grains.

Plans: Emphasis will be on the Georgia-Piedmont study as a pilot effort for determining the aggregate effects of changes in farm technology on output and on optimum size and organization of farms to attain specified income levels, subject to the limitations imposed by the input-output relationships for both crop and livestock enterprises applicable to the area. Optimum combinations of acreage and technology to obtain specified levels of production for the area will also be determined.

Additional work along these lines now in progress in Missouri will also be pursued toward completion. Similar new work is being undertaken in Arkansas, for which there is financial assistance to the State from the National Plant Food Institute.

8. ECONOMICS OF CONSERVATION FARMING FE

Problem: Conservation of soil and water resources has been of growing concern to farmers and farm leaders for years. Despite more than a quarter century of Federal programs to promote and facilitate conservation, many farmers in many areas do not have a working knowledge of the costs or the benefits they can expect from conservation measures and conservation systems of farming. In research appraisals of the obstacles to conservation, many farmers put lack of knowledge as to whether recommended practices will pay as a major reason why they hesitate to adopt conservation measures. Information is needed on costs and returns from conservation practices and systems of farming, and on how specific practices fit into farming systems in local areas.

Program: A continued long-term program of research dealing with costs and returns from conservation measures, organization of farms and cropping systems to effect conservation, timing of returns, and an appraisal of the obstacles to conservation and of the assistance in establishing conservation practices that is available to farmers. Current work is in 4 States in cooperation with State Agricultural Experiment Stations and involves about 5 Federal professional man-years annually.

Progress: A major study of the economics of conservation farming has been in progress in the Ida-Monona Soils Area in Western Iowa since 1949. The results of a third periodic survey on 138 farms, of annual soil losses, farmers' goals of attainable minimum annual soil loss, and farmers' obstacles to greater adoption of erosion-control practices, were reported last year. A publication in process which reports the results will be followed by another, now in preparation, outlining alternative approaches to an alleviation of the obstacles.

Among the obstacles farmers in western Iowa report, lack of knowledge on how a shift to conservation farming would affect costs and returns is outstanding. The lack of knowledge on the benefits of conservation reflects a paucity of information on the effect of conservation practices on the yields of crops. To accurately measure this relationship, additional data were obtained in the Ida-Monona Soils area in 1959 on the yields of corn on 155 randomly selected "on-farm" plots that varied in

the extent of use of conservation practices. Among the conservation practices, contour surface planting appears to have had the most significant effect on corn yields in 1959. The significance of other conservation practices will be indicated by the results of analyses underway. The Agronomy Department of the Iowa Station continued and expanded the work in 1960.

A study is in progress in Wisconsin to ascertain the costs of installing and maintaining soil conservation practices, the increase in the gross and net farm returns in the short- and long-run resulting from adoption of individual or groups of soil conservation practices, and the order of their adoption in typical farm situations to provide most effective use of capital, land, and labor resources. The study is limited to the Fayette Soil Association area in southwestern Wisconsin because of lack of data in other parts of the State. A test of the profitableness of the applicable conservation practices on a typical farm situation on Fayette soil showed a ranking as follows: Terracing, interplant-on-terrace, interplant-on-contour, contour strip cropping, contour cultivation, and field strip cropping. When the optimum organization was determined with choice of conservation practices related to slope of cropland, the combination of practices was as follows: 4 percent cropland - terracing; 8 percent cropland - interplant on terraces; 12 percent cropland - terracing; and 16 percent cropland - contour strip cropping.

Studies of representative farms in the Southern Upland Cotton Area of Tennessee have been concerned with the economic relationships of different levels of conservation farming. The loess soils in this area are highly subject to erosion. The conservation systems were (1) contour cultivation, continuous row crops, (generally practiced at present), (2) contour strip-cropping, continuous row crops, and (3) contour terracing and winter cover crops, continuous row crops. Under these systems annual soil losses, per acre, were estimated to be 19.8 tons, 9.9 tons, and 4.5 tons, respectively. Reductions in yield, as would be expected, follow closely these losses in top soil, declining slowly at first and more rapidly in the latter stages. Using input-output data developed for the area, incomes from alternative farming systems were developed for each of the conservation systems. As an illustration, the following income comparisons were developed for the conservation system employing contour strip-cropping and continuous row crops. On a representative farm of 120 acres of open land, a grade C dairy-cotton system with a minor corn-hog enterprise would return an estimated $3,100 in family labor earnings. Substituting a grade A dairy would increase these returns by roughly $1,000. With cotton-corn-hogs and a 20 beef herd, family labor earnings would be about $3,000. Earnings from these systems compare with an income of $1,400 from this farm operated as a cotton specialty farm with current farming methods. A bulletin reporting the results of this study is near completion.

The economic benefits of mechanical conservation practices in northeastern Kansas are realized over time, far beyond the planning horizon of an individual farmer. Terraces, contour farming, grass waterways, and grade

stabilization structures reduce net income in the shortrun. That is, they would not pay for themselves over a period of 20 to 25 years. This does not attract the individual farmer. However, without such practices deterioration of the land is continuous, and over a long period, such as 75-80 years, yields can be expected to fall to levels where productivity, and hence net income, are seriously impaired. Terracing is expected to stabilize production at the level experienced when the terraces are formed, slightly below the level before terracing. The costs will be absorbed over time through maintenance of productivity. A 240 acre cash grain farm, using an appropriate fertilizer program, will produce a net income of $5,150 that will decline to $4,200 over the long time period. If terraced, the same land would produce a constant return of $5,100. A progress report and an Experiment Station Bulletin are to be completed this year. This project has been discontinued.

Plans: Studies in progress will be continued to completion, and new studies of important conservation problems in the Great Plains, Corn Belt, and South will be initiated to maintain work on conservation economics at about current levels in the research program.

Publications: Potential Crop and Livestock Production and Net Farm Income on Dominant Soils in Northwest Wisconsin. John R. Schmidt and Rudolph A. Christiansen. Wis. Agr. Expt. Sta. Bul. 219. May 1960.

Planning for Maximum Income in Soil Conservation. Rudolph A. Christiansen and John R. Schmidt. Soil Conservation. Sept. 1959.

Costs and Returns from Sheep in Tennessee. H. A. Henderson and S. W. Atkins. Tenn. Agr. Expt. Sta. Bul. 306. Dec. 1959.

Effect of Cropping Practices on Yield, Soil Organic Matter, and Erosion in the Pacific Northwest Wheat Region. G. M. Horner, M. M. Oveson, G. O. Baker, and W. W. Pawson. Pacific Northwest Agr. Exp. Sta. Regional Research Bul. 1. July 1960.

9. PLANTING AND FERTILIZING EQUIPMENT AE

Problem: To determine the most effective and economic ways of establishing field crops and applying fertilizer.

Program: A continuing long-term program of cooperative research involving studies of fertilizer placement, and including, in most cases, seed placement investigations, is in progress at 34 locations, within the bounds of 16 states (Alabama, Arizona, Georgia, Indiana, Louisiana, Maryland, New Mexico, Mississippi, Michigan, New York, New Jersey, Nevada, Tennessee, Texas, Washington, and Wisconsin). Approximately 5 man-years are devoted to this work.

Progress: Equipment for Pasture and Hayland Establishment. Forty-one field experiments on the establishment of pastures and haylands were put in cooperatively. Many experiments showed quicker and more vigorous stands of forages with precision planting and placement of fertilizer in comparison with the common method of broadcasting seed and fertilizer.

In Wisconsin alfalfa yielded 4548 lbs. per acre where fertilizer was placed 1" to side, 1" below drilled rows, and 3287 lbs. per acre (dry hay) with the so-called "improved common method" of broadcasting seed and fertilizer. The probable variance between seasons will require results of several seasons to make proper evaluation of the methods being studied. In drilling winter grains (rye) in Bermuda sod in Maryland with heavy duty grassland drills, beef gains on the growing season of pastures have been increased 20 to 25% as indicated in two full years of study. Fertilizer is placed directly below the drill rows of rye and rows were spaced 8", 10", 16" and 20".

Difficulty was encountered in getting stands of some of the grassland plantings in the Southwest. Where satisfactory stands were made, very little response was obtained from the added fertility or placement of fertilizer. Pitting in rangeland showed benefits in establishing desired grasses on the lighter soils and when enough rainfall occurs for runoff. No benefit was shown by pitting where there was no appreciable runoff from unpitted areas.

In the Southeast, response to precision placement of seed and fertilizer was obtained on Sericea Lespedeza and on alfalfa. In a mixture of oats-ryegrass-crimson clover in Louisiana, three seasons show consistent yield increases of 10% to 30% with band placement of fertilizer on drill rows in comparison with common broadcasting methods.

Fertilizer Placement Equipment for Crops. Twenty field experiments were conducted at several locations. In 1959, some of the largest response was recorded on the 3-year study on small grains in Michigan where precise placement of fertilizer was compared to the common method of fertilizer placed with the seed while drilling. In rows of oats spaced 11" apart, 14.8 bushel yield increase per acre was secured with a continuous band of fertilizer 1" to the side and 2" below the seed. In the winter wheat experiment, yield increases up to 10 bushels per acre were recorded with the side placement of fertilizer.

In using phosphate fertilizers on tomato plants in Georgia, heavy fertilizer rates below the seed at time of planting gave greater production of marketable tomatoes. The plants were transplanted in New Jersey and grown for fruit which produced 18 tons per acre from seedlings that had received 10 lbs. P_2O_5 per A and 25 tons from those that got 130 lbs. And probably equal if not more significant was the increase of early production of tomatoes. The early production varied from 1/4 ton to 1-1/2 ton/acre. The net returns to the grower for early production are many times larger than production during the peak of the season.

Fertilizer Application Equipment for Cotton. The use of fertilizer is increasing in the Texas High Plains area, but very little equipment is adapted to the type of seedbed preparation and planting used. A mounting for a small disk opener was designed for the application of liquid fertilizer with the new plateau profile planter. Operation was satisfactory but responses were not measured due to hail damage.

Cotton Planting Equipment. In spacing and rate studies in Mississippi, neither the hill spacings of 7.5, 14.5, and 21.8 inches nor the seeding rates of 12, 23, and 31 pounds per acre had any effect on cotton yield and picking efficiency. The analysis also revealed that heavy drilling and hand thinning did not significantly improve seedling emergence, yield, or picker efficiency when 30.8 pounds of seed were drilled per acre. It may be noted that plant populations ranged from 28 to 60 thousand per acre, yet there was no significant difference among yields. However, the rate of seed planted had a highly significant effect on the percent of seedling emergence. Contrary to previous work in other areas, the lowest rate of seed per acre resulted in the highest percent emergence.

In the High Plains area, the plateau profile planter produced best stands on loamy fine sand and clay soils compared to flat and shallow furrow row profile plantings. There was no difference on fine sandy loam. There was a general trend for the shallow profiles to give the best results in all three soils. More early emergence was obtained for plantings when the seed firming wheel was used on all three soil types. Pressing the covering soil improved stands on the clay loam soil but has been found to decrease emergence on sandy and sandy loam soils in this area. The use of rubber flap wheels for pressing covering soil and scrapers on the sides of seed press wheels greatly reduced soil sticking problems in the heavy soils.

In a silt loam soil at Pecos, Texas, a curved seed furrow opener, modified with a furrow sole compressor, combined with 1-1/2 to 2 inches loose soil covering gave the best results. When using a lister-type planter in this area the type seed furrow opener and seed press wheel made no difference.

A plastic mulch formed by a strip of clear polyethylene film placed over the planted seed row speeded emergence on all of the soil types mentioned above. The mulch was removed immediately after emergence and the gain in plants per foot laster 3 weeks at most locations.

Plans: Study of drilling winter grains in Midland Bermuda and for pasture will be continued. Investigation of plastic and paper mulches, and light asphalt soil surface coating will be initiated as methods of improving establishment of range grasses. Investigation will be continued of methods of drilling legumes into grass sod as a method of re-establishing desirable grass-legume ratios in pasture. Work on plastic mulches and planting equipment for cotton will be continued.

Publications: Equipment for Establishment and Maintenance of Grassland. W. C. Hulburt. Grasslands, American Asso. for the Advancement of Sci: 117-123. 1959.

Growth and Yield Characteristics of Spring Oats and Winter Wheat as Affected by Various Placements of Fertilizer. L. A. Robertson, C. M. Hansen, R. F. Dudley, H. N. Brown and H. D. Foth. Proc. of the Thirty-Fifth Annual Meeting of the National Joint Committee on Fertilizer Application by the National Plant Food Institute: 19-20. 1959.

Cotton Planting Rate Studies on the High Plains. L. L. Ray, E. B. Hudspeth, Jr., and E. R. Holekamp. Texas Agri. Exp. Station MP-358. May 1959.

Seed and Fertilizer Placement Studies on Selected Native Grasses at Big Spring. E. B. Hudspeth, Jr., Judd Morrow, Earl Burnett and Norman Welch. Texas Agri. Exp. Sta. Progress Report 2097. July 8, 1959.

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Alteration of the Microclimate of the Seed Zone. T. J. Army and E. B. Hudspeth, Jr. Agron. Jour. 52: 17-22. 1960.

Cotton Planting Equipment Tests at Pecos, 1959. Emmett R. Holskamp and E. L. Thaxton, Jr. Texas Agri. Exp. Sta. Prog. Rpt. 2122. Jan. 10, 1960.

Cotton Emergence Increased with Polyethylene Covers. E. R. Holekamp. Tex. Agri. Exp. Sta. Prog. Rpt. 2113. Oct. 24, 1959.

VII. FERTILIZER IMPROVEMENT, EVALUATION, AND DISTRIBUTION

1. FERTILIZER MATERIALS DEVELOPMENT AND REFINEMENT SWC

Problem: The nature of a nutrient-bearing substance or a soil amendment, which is definable in terms of measurable characteristics, determines its suitability for use under established manufacturing conditions or under particular cultural practices. High efficiency in technical and farm uses is attainable only by searching out uses in which particular materials meet the needs most effectively. To this end, properties of materials must be geared to desired performance.

Program: The continuing long-term program concerned with new materials, processing for improved performance of product and close characterization of products, which involves studies of the chemistry, technology and utilization of nutrient-bearing materials, is conducted at Beltsville, Maryland, and, as the occasion demands, in cooperation with the Tennessee Valley Authority and other Federal agencies, State Experiment Stations, and the fertilizer industry. It involves about 9 professional Federal man-years annually.

Progress: Studies pointing to materials development and refinement that have been stressed during the year are concerned with urea, biuret, sundry nitrogen compounds not presently used as fertilizers, wet-process phosphoric acid, phosphate rock, agricultural limestone, suitability of cement-kiln dust for agricultural use, and glass as a carrier for fertilizer zinc.

The possibility of improving the performance of urea used as a top-dressing by inhibition of its enzymatic hydrolysis with the use of small amounts of a suitable additive holds some promise. Blocking of a small fraction of the sulfhydryl groups in urease by reaction with a heavy metal or with organic or inorganic reagents inhibits its urea hydrolyzing power. Commercially available urease preparations are being tested for development of a standard laboratory procedure and technique for measuring urease activity looking to a systematic investigation of potential inhibitors or retardants as additives to fertilizer-grade urea.

Biuret, a frequent constituent of fertilizer-grade urea, does not combine with formaldehyde under conditions that normally obtain in urea-form preparation. Biuret formaldehyde products were formed after prolonged digestion at higher temperatures. It now appears that these complexes possess the methylol structure instead of the methylene structure characteristic of urea-form. Test preparations of these complexes showed slightly higher 3-week nitrification indexes, though markedly lower 15-week indexes, than biuret.

Concern for new materials that are slowly available and non-burning prompted an exploratory study of nitrogen materials not now used as fertilizer. Examination of such materials as to suitability for fertilizer use is in progress.

Envisioned work on methods for conditioning wet-process phosphoric acid to render it suitable as a fertilizer commodity was completed during the year. The basic requirement for movement of this acid in trade is a negligible amount of sediment deposited in the tank car at the delivery point. Acid meeting this specification can be made either by treatment of the crude acid produced in long-established processes for the removal of sediment-forming impurities, or by modification of the production process in ways that prevent occurrence of these impurities in the acid - general approaches feverishly followed, more or less secretly, by the industry during the past 2 or 3 years, until now nearly all producers offer to the market reasonably satisfactory acid.

Porosity and pore-size distribution are important factors affecting phosphate rock reactivity. In fertilizer processing and use phosphate materials are regularly contacted by reactive fluids, for example, soil solutions, mineral acids, gaseous ammonia, and aqueous solutions of nutrient substances and fertilizer salts generally. The response of the material to the action of the fluid depends upon its physical properties, as well as upon its chemical composition, yet the influence of physical character has not been adequately explored. Market competition has stimulated lively interest in comparative studies of available products, which provide definitive information as to likely performance in specific uses--a matter of special significance in phosphate rock and triple superphosphate utilization.

Work on the distribution of nutrient elements in agricultural limestone from different sections of the country was continued for the purpose of extending the results for silicon, with which the gross trace-nutrient content shows high statistical correlation. The results on 194 limestones from 35 States show that the trace- and minor-nutrient complement of limestone varies from region to region and is generally higher in prepared stone than in rock direct from the quarry. Stone from the West North Central region generally shows the higher gross amount of these constituents, whereas that from Middle Atlantic States ranks highest in potassium; that from New England, in zinc; and that from the East South Central region, in sulfur.

The liming and fertilizer values of flue dust from cement kilns were pursued further in a greenhouse experiment with a set of dusts typifying the rather wide composition range of this material (up to 13% K_2O).

Work was begun on the development of glass carriers of zinc. The pattern of approach will be much the same as that used in the study of boron glass.

Plans: Work is expected to continue at about the same overall level with emphasis on (1) conditioning urea for prevention of enzymatic hydrolysis, (2) nitrogen carriers for slow nutrient release, (3) physical character of phosphate rock, and (4) characterization of zinc-bearing glass as a nutrient source.

Publications: Urease Bibliography. R. M. Creamer. SWC Plant Food Memo. Rept. No. 24: 36. Dec. 21, 1959.

Colorimetric Determination of Aluminum in Acid Solutions of Phosphate Rock. W. A. Jackson. J. Agr. Food Chem. 7: 628-630. 1959.

Steam Distillation of Fluorine from Perchloric Acid Solutions of Aluminiferous Ores. E. J. Fox and W. A. Jackson. Anal. Chem. 31: 1657-1662. 1959.

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2. MIXED-FERTILIZER TECHNOLOGY SWC

Problem: Difficulty with maintenance of a free-flowing and drillable character of mixed fertilizers generally increases with the nutrient content. Consequently, the continued trend to goods of higher and higher analysis places increasing strain on conventional processing procedures, which often require modification in the interest of preservation of product quality. Concern must also be exercised for the effects on processing and performance of nutrients other than N, P, and K, which are removed in the quest for high analysis, or which are desirable additions to fertilizers sold in some regions.

Program: A continuing long-term program concerned with improvement in the physical nature of mixed fertilizers through modified processing, agronomic quality of the nutrient content, incorporations of trace nutrients and preparation of special fertilizers for experimental use, which involves studies on the chemistry, physics and technology of processing mixed fertilizers, is conducted at Beltsville, Maryland, and, as the occasion demands, in cooperation with the Tennessee Valley Authority and other Federal agencies, State Experiment Stations and the fertilizer

industry. It involves about 6 professional Federal man-years annually.

Progress: The influence of the physical nature of ingredients on the behavior of fertilizer mixtures in granulation processes was continued with emphasis on commercial makes of triple superphosphate in search for useful correlations between granulative performance and measurable physical properties. Porosity, in particular pore size, appears to be a critical property, which permits a useful classification of superphosphate granulative character.

An exploratory study, noted last year, of the compaction process as a possible method for fertilizer granulation is still in progress.

Projected work on nitrogen loss from mixed fertilizers containing ammonium nitrate during processing and storage was completed. Observed losses occurred during processing rather than in storage, and temperature control appears to be the key to effective prevention.

The nutritive quality of phosphorus in mixed fertilizers depends on the reactivities and existing proportions of three classes of compounds, which are characterized by conventional laboratory tests as water-soluble available compounds, like the ammonium phosphates, water-insoluble available substances typified by dicalcium phosphate, and unavailable forms such as apatite. Crop response to the separate forms was studied extensively in the distant past. Since, however, the pattern of response to two or more substances in mixture is not necessarily predictable from the responses to the separate substances, the role of the respective forms as determinants of the overall reactivity, and therewith the nutritive quality of their economic mixtures is the subject of a study. Last year attention was turned from the role of water-soluble phosphates to the delineation of the influence of small increments of unavailable forms. Emphasis on this difficult aspect of the study was continued, and the experiment is still in progress. The main difficulty resides in making an adequate characterization of the nutrient in the mixture.

Incorporation of trace-nutrient carriers in mixed fertilizers generally results in a lowered trace-nutrient reactivity, and the added substance may seriously worsen the physical character of the mixture. The latter circumstance is typified by the addition of zinc sulfate to 3-12-12 fertilizer and other 1:4:4 grades--a problem dealt with in a recent publication. The work concerned with changes in manganese, copper and zinc reactivity upon incorporation of their carriers in mixed fertilizer is still in progress.

Technological advances and changing consumer requirements give rise to gradual shifts in mixed-fertilizer composition, which are not necessarily to the best long-term interests of the user. Hence, it is desirable to have periodic checks on the composition of marketed goods, as was done for the years 1949-50 and 1955-56 by analyzing 400-500 samples collected in accordance with a country-wide sampling design. Results presented in a recent paper cover the distribution of phosphorus among conventional reactivity levels, moisture, ash, carbonate carbon, acid-forming character,

and particle size. A noteworthy change indicated for the 6-year period is a decline in water-soluble phosphorus from 50 to 46% of the available phosphorus. The study is presently being extended to cover calcium, magnesium and sulfur.

Production of radioactive fertilizers for experimental use by Federal, State and non-government agencies was continued at about the same level. Two special high-level tasks were performed--sand labeled with scandium and glass beads labeled with barium.

Plans: The work is expected to continue at about the same overall level with emphasis on (1) granulation technique and effect of nature of ingredients on processing (2) nutritive quality of water-insoluble phosphorus content, (3) evaluation of incorporated trace nutrients, and (4) completion of study of mixed-fertilizer composition.

Publications: The Effect of Some Processing and Storage Conditions on Nitrogen Loss from Mixed Fertilizers. B. M. Olive and J. O. Hardesty. Com. Fert. 100(3): 24-28. 1960.

Zinc Induced Caking in Mixed Fertilizers and Its Counteraction. J. H. Caro, H. P. Freeman, and J. H. L. Marshall. Agr. Chem. 15(1): 34-37. 1960.

Pan Granulators for Fertilizers. J. O. Hardesty. Agr. Chem. 14(12): 30-32, 98-100. 1959.

Segregation of Fertilizers. W. L. Hill. Agr. Chem. 15(1): 27-28. 1960.

Properties of Marketed Fertilizers--Physical and Chemical Characteristics of Mixed Fertilizers and Superphosphates Marketed in 1955-56. Part I. Forms and Solubility of Phosphorus. K. G. Clark, W. M. Hoffman, and H. P. Freeman. Part II. Reaction, Particle Size and Inert Matter Contents. K. G. Clark, T. G. Lamont, R. R. Winkler. J. Agr. Food Chem. 8: 2-13. 1960.

3. FERTILIZER CHARACTERIZATION FOR MARKET QUALITY CONTROL SWC

Problem: Adequate examination of marketed fertilizers and amendments for compliance with specifications as to quality, demands reliable sampling procedures and analytical methods. These techniques require periodic improvement, so that the testing laboratory can be kept abreast of scientific advances in fertilizer making and use.

Program: A continuing long-term program concerned with improvement of precision of assay, conservation of the analysts' time and adaptations for new products by modification of procedures in use and by development of new procedures, conducted at Beltsville, Maryland, in cooperation with the Association of Official Agricultural Chemists and the Association of American Fertilizer Control Officials, and, as the occasion arises with the Tennessee Valley Authority, National Plant Food Institute, the

fertilizer industry and producers of amendments. It involves about 5 professional Federal man-years annually.

Progress: In further pursuit of information adequate for trade needs and consumer protection on the quality of urea-formaldehyde reaction products, both alone and in mixed fertilizers, and related materials of possible interest as slowly soluble nitrogen carriers, the reactivity of sundry materials was indexed with the use of nitrification tests in soil media and of solubility measurements by standard procedures for fertilizers. These findings provided background for a collaborative study of the applicability to urea-form mixtures of the official procedure for the laboratory evaluation of preparations of urea-form. Accordingly, the Association of Official Agricultural Chemists revised the first action to include such mixtures at the Annual Meeting in October 1959.

The use of urea in mixed fertilizers created a need for and resulted in the adoption of an official method for determination of the urea content of mixed fertilizers. It also created an important, but less widely recognized, need for modification of the official methods for determination of ammoniacal nitrogen. Neither of the present official methods is applicable to mixtures containing both urea and soluble phosphate. Separation of the phosphate to yield solutions suitable for determination of both ammoniacal and urea nitrogen is under exploration.

The collaborative study (under way last year) of methods for determining biuret in urea and in mixed fertilizers was concluded, and procedures were adopted by the Association of Official Agricultural Chemists at the Annual Meeting in October 1959.

Work on procedure for direct determination of available phosphorus was completed; first action for the method to become official is anticipated this fall.

A study was made to determine the reliability of screen analyses of phosphate rock. The indicated precision with confidence of 95% (analysis in duplicate) is $\pm$ 1.27% for the -100-mesh determination and $\pm$ 2.51% for the -200-mesh determination.

The National Plant Food Institute's sampling experiment, in which the Department participated, was completed; publication of the full report is expected this fall.

Plans: The work is expected to continue at about the same overall level with emphasis on (1) determination of forms of nitrogen in mixed fertilizers and (2) refinements in procedure for determination of available phosphorus.

Publications: Recent Developments and Current Problems in Inorganic Analytical Chemistry. K. D. Jacob. Anal. Chem. 31: 1945-1949. 1959.

Fineness of Commercial Florida Land-Pebble and Other Phosphates Used in Superphosphate Manufacture. W. M. Hoffman, E. J. Koch, and E. J. Pedersen. J. Agr. Food Chem. 8: 178-182. 1960.

Thermal Properties of Quinoline Molybdate. W. W. Wendlandt and W. M. Hoffman. Anal. Chem. 32: 1011-12. 1960.

4. AGRICULTURAL CHEMICAL ADDITAMENTS SWC

Problem: The use of fertilizer as a vehicle for soil additions of pesticides and growth regulators is indicated when the appropriate time for treatment with the agricultural chemical and with the fertilizer are the same. As regards fertilizer technology, the problem is to determine the compatability of the chemical with the fertilizer and to devise procedures for achieving a suitable blend.

Program: A continuing program concerned with testing, as the occasion demands, the compatibility of certain agricultural chemicals with sundry grades of fertilizer, conducted at Beltsville, Maryland, in cooperation with interested Divisions of the Agricultural Research Service and with concerned industries. It involves about 1 professional Federal man-year annually.

Progress: Projected work on fertilizer pesticide mixtures was completed with the publication of a recent paper. A newly-begun study is concerned with the use of fertilizer as a vehicle for a prospective growth depressant for cotton among other crops.

Plans: The work is expected to continue at about the same level with emphasis on the growth depressant, phosphonium.

5. FERTILIZER SUPPLIES AND PRODUCTION FACILITIES SWC

Problem: Reliable information on resources, supplies and production facilities in the United States and on international developments concerned with fertilizers that may affect the domestic fertilizer economy is needed by planning authorities in both government and industry.

Program: A continuing long-term program concerned with periodic surveys of production facilities as to capacity, products, location, market areas and the like, and with systematic review of sundry reports and trade notes, both domestic and foreign, conducted at Beltsville, Maryland, in cooperation with government agencies and private industries at home and abroad. It involves about 1 professional Federal man-year annually.

Progress: The status of synthetic ammonia production in the United States was the subject of an invited address. The annual capacity is now about 4-1/4 million tons of nitrogen, more than one-fourth of which lies in the West South Central region. Capacity to produce is 1.5-fold the 1950 figure; consumption for direct application, on the other hand, has gone up to 7-fold.

Information on fertilizers was supplied to the International Cooperation Administration, the Organization for European Economic Cooperation and 61 foreign visitors.

Potassium nitrate, a subject of study in the past and long known to be an effective fertilizer compound, though heretofore it could not compete costwise with other potassium carriers, is to be produced for fertilizer use in a plant soon to be erected in the lower Mississippi Valley. Initially, production is expected to go to the formulation of low-chloride mixed fertilizers for tobacco among other crops. A growing general use in very high-analysis mixtures is anticipated.

Plans: The work is expected to continue at about the same overall level with emphasis on domestic superphosphate production facilities.

Publications: Notes on Fertilizer Facilities in Asia. K. D. Jacob. SWC Spec. Rept. No. 86. Aug. 10, 1959.

Fertilizer Production and Technology. K. D. Jacob. Advances in Agronomy 11: 233-332. 1959.

Observations and Comments on the First World's Agricultural Fair in India. M. A. Norland. SWC Spec. Rept. No. 90. March 25, 1960.

Visit to Florida Phosphate Fields. J. O. Hardesty. SWC Spec. Rept. 84: June 9, 1959.

Anhydrous-Ammonia--Domestic Productive Capacity and Consumption as a Fertilizer Material. J. R. Adams. Agr. Ammonia News 10(1): 23, 25, 43. 1960.

6. CONSUMPTION TRENDS AND USE PATTERNS SWC

Problem: Reliable information on consumption, consumption trends and use patterns of fertilizers and amendments is needed by planning authorities in both government and industry.

Program: A continuing long-term program concerned with annual surveys of commercial fertilizers of all kinds as regards gross tonnage and amount of nutrient, with studies to disclose trends in fertilizer use with respect to criteria of special interest, such as preferred grade, chemical content, physical character, etc., and with the periodic development of crop use patterns is conducted at Beltsville, Maryland, in cooperation, as the occasion demands, with Federal agencies, in particular the Farm Economics Research Division and the Commodity Stabilization Service, with fertilizer control offices and other State agencies, and with companies composing the fertilizer industry and their associations. It involves about 2 professional Federal man-years annually.

Progress: The annual survey of fertilizer consumption in the United States for the year 1958-59 was completed. Consumption of commercial fertilizers

of all kinds amounted to 25,300,000 tons (2,800,000 tons above the preceding year) carrying 7,400,000 tons of N + available P_2O_5 + K_2O, of which about 67% was used as mixed fertilizer. The average nutrient content (N + available P_2O_5 + K_2O) of mixed fertilizer was 30.67% in comparison with 30.22% the year before.

Two requests for special discussions were concerned with the fertilizer situation in North Carolina and with trends in fertilizer ingredients and use in the Northeast.

Crop-use patterns of fertilizers in the United States were developed from Bureau of Census data for the year 1954. A similar study, with marked improvements, based on the 1959 Census of Agriculture is in progress.

Plans: The work is expected to continue at about the same level with emphasis on crop-use patterns and on elaboration of the findings from the annual consumption survey.

Publications: Preliminary Report on Consumption of Commercial Fertilizers and Primary Plant Nutrients in the United States Year Ended June 30, 1959. Walter Scholl, M. M. Davis, E. I. Fox, and C. A. Wilker. Agr. Chem. 15 (2): 30-32, 120. 1960. Com. Fert. 100(2): 14, 17-18. 1960.

Trends in Fertilizer Ingredients and Use. K. G. Clark. Proc. Eastern States Farmers' Exchange Agron. Conf. 22nd Ann. Mtg: 55-73. March 1-2, 1960.

Consumption of Commercial Fertilizers and Primary Plant Nutrients in the United States Year Ended, June 30, 1959. Walter Scholl, M. M. Davis, and C. A. Wilker. ARS 41-19-2. Aug. 1960.

7. LIQUID FERTILIZER DISTRIBUTION BY LOCAL COOPERATIVES FCS

Problem: The use of liquid nitrogen fertilizers by farmers has increased rapidly in many areas. Studies of local cooperatives now distributing these products efficiently can furnish useful information for groups interested in providing such services.

Program: A 3-year study of liquid fertilizer distribution dealing with (1) the type, size, cost and adequacy of equipment used; (2) operating practices and policies followed; and (3) problems and possibilities for improving distribution services to farmers. The study involves three or more geographical areas with different distribution programs and requires one professional man-year annually.

Progress: An initial study of liquid nitrogen distribution by 17 local cooperatives in Kansas and Nebraska has been completed and published. Some of the findings were as follows: Anhydrous ammonia was handled by 12 associations, nitrogen solutions by 14, and both by nine. Anhydrous, having been used in the area longer, comprised 70 percent of all nitrogen and 66 percent of all fertilizers sold by the cooperatives studied. The most commonly used steel bulk storage tanks for anhydrous ammonia was found to

be 30,000-gallon capacity tanks. The minimum investment for plant facilities including this size tank was $13,400. The cost for nitrogen solutions plant facilities ran approximately one-third to one-half that of anhydrous ammonia. The difference in cost was primarily because anhydrous equipment must be able to withstand high pressure. Higher margins were obtained on liquid than on dry fertilizers. Gross margins on anhydrous ammonia averaged 23 percent of sales. Patronage refunds averaged 16 percent. Twelve of the 17 associations reported that liquids were causing dry nitrogen sales to decrease. Some of the services offered were: fertilizer fieldman to work with patrons in planning their fertilization programs and to assist with application problems; application equipment on a rental basis or complete custom application services at reasonable rates for patrons not owning equipment; soil sampling service; and a spare parts inventory maintained for patrons owning application equipment. Seven suggestions for improvement were made.

Data for a companion study of local cooperatives in the Pacific Northwest have been obtained.

Plans: Data already obtained will be analyzed and the publication of the results near the end of 1960 will complete the study. Further studies, especially of liquid mixed fertilizer distribution, will be continued in 1960-61. New work on local bulk blending and storage of fertilizers will be started in 1961-62.

Publications: Liquid Nitrogen Distribution by Local Cooperatives in Nebraska and Kansas. B. H. Pentecost. USDA, FCS Gen. Rpt. No. 82. July 1960.

A Summary of Current Program and
Preliminary Report of Progress

SOILS, WATER AND FERTILIZER RESEARCH

of the
United States Department of Agriculture
and cooperating agencies

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

There is included under each problem area in the report, a brief and very general statement on the nature of the research being conducted by the State Agricultural Experiment Stations and the professional manpower being devoted by the State stations to such research. Also included is a brief description of related work conducted by private organizations. No details on progress of State station or industry research are included except as such work is cooperative with U.S.D.A.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having an interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last two years. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington. D. C.
December 14, 1962

OTHER COMMODITY AND FUNCTIONAL REPORTS

A progress report similar to this one is prepared for use by each of the following research and marketing advisory committees:

Citrus and Subtropical Fruit
Cotton and Cottonseed
Dairy
Deciduous Fruit and Tree Nut
Forage, Feed and Seed
Forestry
Grain
Livestock
Oilseeds and Peanut
Potato
Poultry
Rice
Sheep and Wool
Sugar
Tobacco
Vegetable
Economics
Farm Equipment and Structures
Food and Nutrition
Food Distribution
Home Economics
Transportation and Storage

Two additional reports of progress are prepared in order to make available the complete research program. They are:

Ornamentals and Other Miscellaneous Commodities
Other Research - Cross Commodity

ORGANIZATIONAL UNIT REPORTS

All of the material in the commodity and functional reports listed above is the same as that found in the 20 division and 3 service research reports listed below.

Agricultural Research Service (ARS)

Agricultural Engineering
Animal Disease and Parasite
Animal Husbandry
Crops
Entomology
Soil and Water Conservation
Utilization -- Eastern
Utilization -- Northern
Utilization -- Southern
Utilization -- Western
Human Nutrition
Clothing and Housing
Consumer and Food Economics

Agricultural Marketing Service (AMS)

Market Quality
Transportation and Facilities

Economic Research Service (ERS)

Farm Economics
Marketing Economics
Economic & Statistical Analysis
Foreign Development & Trade Analysis
Foreign Regional Analysis

Other Services

Farmer Cooperative Service (FCS)
Forest Service (FS)
Statistical Reporting Service (SRS)

A copy of this report or any of the others listed above may be requested from David J. Ward, Executive Secretary, Soils, Water and Fertilizer Research Advisory Committee, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

TABLE OF CONTENTS

INTRODUCTION

This is ONE part of a TWO part report of cooperative U.S.D.A. research on soils, water, and fertilizer.

This part of the Soils, Water, and Fertilizer report deals with some of the research conducted by the Watershed Management and Recreation Research Division of the Forest Service, the Agricultural Engineering and Crops Research Divisions of the Agricultural Research Service, and the Farm Economics Division of the Economics Research Service. The other and larger part deals with the research of the Soil and Water Conservation Division of the Agricultural Research Service. Only a brief description of the related work of the State Experiment Stations and industry is included.

Under each of the Problem Areas there is a statement describing the program of work under way and the professional man-years devoted to the major kinds of research included. The relative scope of the total research effort on soils, water, and fertilizer is indicated by the approximate number of professional man-years employed; 560 by U.S.D.A., 479 by the State Experiment Stations and several hundred by industry and other organizations.

A brief report of progress and significant findings for U.S.D.A. and cooperative progress is given for each phase of the research program.

Research by USDA

Farm research comprises investigations on soil and water conservation, weed control, soil machine relationships, and planting and fertilizing operations and equipment. This research is conducted by the Agricultural Engineering, Crops, and Soil and Water Conservation Research Divisions of the Agricultural Research Service, and in Fiscal Year 1962 involved about 446 professional man-years.

Economic Research is concerned with land and water use and development, conservation practices, fertilizer use, and cropping systems. The work reported herein is done by the Farm Economics Research Division of the Economics Research Service. Approximately 19 professional man-years were devoted to this work in Fiscal Year 1962.

Forest area watershed research is concerned with increasing water yields and protecting and rehabilitating forest and related rangeland watersheds that are sources of damaging runoff and sediment.

Research by State Experiment Stations

There is included under each problem area a brief and very general statement on the nature of the research being conducted by the State Agricultural Experiment Stations and the professional manpower being devoted by the State Stations to such research.

Consolidating this information for the entire field of interest, we find that in Fiscal Year 1962 a total of about 479 professional man-years were spent by the State Agricultural Experiment Stations on soil, water and fertilizer research.

Soil, water and fertilizer research in 1962 was in progress in each of the State Agricultural Experiment Stations. Studies under way were carried out by research workers in departments of Agronomy, Soil Science, Agricultural Engineering, and to a lesser extent in various plant science departments.

Professional man-years devoted to soil, water and fertilizer research at the State Agricultural Experiment Stations in 1962 were: 19, hydrology and sedimentation processes; 9, hydraulics of irrigation and drainage; 9, conservation of water supplies for agricultural use; 10, properties and management of saline and sodic soils; 12, wind and water erosion control; 28, moisture conservation for crop and range lands; 146, nutrient requirement, balance, and crop response; 50, soil physical properties; 37, soil chemical properties; 20, soil microbiology; 41, soil-water-plant relationships as they affect land and water use; 14, fertilizer technology; 20, soil and water management practices for specific crops; and 63, soil genesis and morphology relating to soil classification.

In addition, closely related research is in progress on the development of tillage, planting and fertilizing machinery; on the development of irrigation and drainage design principles and practices; and on the economics of water use and conservation practices. Research is also in progress on animal nutrition in relation to properties and characteristics of soils and plants.

The above figures include a number of man-years devoted to several regional research projects on which scientists are cooperating to investigate problems of regional and national concern.

No details on progress of State station research are included in this report except as such work is cooperative with the U.S.D.A.

Research by Industry and Other Organizations

Research in this general area is carried on by fertilizer manufacturers, farm equipment manufacturers, canning and processing companies, and on economic aspects by endowed universities, private research foundations, and government, including State (other than land grant) agencies.

Research by manufacturers is, of course, aimed at improving the profits of the industry, and findings are not usually available to the public. These industries will continue to carry on research, and particularly developmental testing to improve their products. They will, however, expect USDA and the States to carry on the research on principles, and functional requirements that underlie progress. Research by private foundations or by universities with foundation funds on water resource problems will undoubtedly be increased. It is estimated that several hundred professional man-years are devoted to this work.

SOIL - MACHINE RELATIONSHIPS

Agricultural Engineering Research Division, ARS

Problem. The substitution of the internal combustion engine for animal power has been the major influence on the farmer's productivity during the first half of the twentieth century. There have been important developments in the tractor chassis and its accessories, such as tricycle gear, power take-off, implement mounting, hydraulic controls, and pneumatic tires, but there is still a lack of fundamental knowledge and understanding of the method whereby tires and tracks transmit forces to the soil in developing traction. In view of the tremendous amount of power and energy which is used every year in farm field operations, all factors which may affect the efficiency of this use should be continually studied for potential improvements in efficiency.

There is need for basic information on how traction is developed by tires and tracks, and need for improved traction, and transport equipment. There is evidence that compaction of soils is becoming more common because of the increasing size of tractors and the more complete mechanization of field operations, particularly harvesting, which usually must be done at a given date regardless of the soil conditions; thus, associated with tire and track research is a need for study of methods of reducing soil compaction.

Tillage of the soil is the greatest consumer of power in the production of crops in the United States today. Some type of tillage operation is considered necessary prior to the growing of almost all crops. Despite this great need and cost, the tillage tools which are generally used have remained essentially unchanged since their invention, or most radical improvement, nearly 100 years ago, and very few innovations since have survived the tests of improved crops response and/or reduced cost of operation. While some tillage is needed for nearly all crops, there is good evidence that much unneeded and in some cases detrimental tillage operations are performed. The soil is a very complex physical system, containing inorganic and organic solids, liquids and gases, and its reactions to forces, manipulation, temperature, and water is unlike any other simple material. In view of the wide-spread use of, and great power consumption by, tillage, there is a need for expanded basic research to give more precise information on the inter-relationship of tillage, soil physical conditions, and plant growth; on the effect of soil mechanics upon the tillage operation; on the effect of equipment mechanics on the tillage operation; on mathematical methods which can be used to predict the effect of various forces on the soil; and on tillage methods and systems of equipment which are compatible with conservation farming practices. Intensive research is needed to determine the optimum tillage requirements, based on costs and crop response, for various soil, climatic and crop conditions.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers and soil scientists engaged in both basic studies and the application of known principles to solve problems dealing with the relationships between soil-engaging equipment and soil reactions. The research findings are applicable to tillage implements, tractive and transport equipment (such as tires, wheels, and crawler tractor tracks), and soil moving equipment (such as land forming and road building equipment). Work is cooperative with the State Agricultural Experiment Stations at Auburn, Alabama; Ames, Iowa; Athens, Georgia; State College, Mississippi; and East Lansing, Michigan. USDA personnel working on this project are stationed at Auburn, Alabama, and Ames, Iowa. Much of the work of the laboratory at Auburn is with manufacturers of implements and equipment for use in agriculture. The research is of a fundamental nature of value to the entire industry and directly and indirectly to farmers. It consists of theoretical analyses, basic laboratory studies, controlled soil bin tests, and field observations.

The Federal scientific effort devoted to research in this area totals 7.3 professional man-years. Of this number 1.0 is devoted to traction and transport devices and soil reaction; 1.0 to the effect of tillage practices on plant growth; 1.2 to the measurement of soil physical properties; 1.5 to equipment mechanics; 0.5 to the effect of soil mechanics; 0.5 to methods of mathematical analysis; 1.0 to systems of equipment for conservation farming; and 0.6 for program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 13.0 professional man-years divided among subheadings as follows: 0.8 on traction and transport devices and soil reaction; 6.9 on the effect of tillage practices on plant growth; 0.6 on equipment mechanics; 0.7 on the effect of soil mechanics; 2.0 on methods of mathematical analysis; and 2.0 on instrument development for study of soil stresses. The current program is divided among the Regions as follows: North Central Region 6.1 professional man years; Northeastern 1.3; Southern 2.1; and Western 3.5.

Industry research in this area is chiefly by manufacturers of agricultural tractors and tillage equipment, and agricultural tractor tires. It is estimated that in 1961 Industry made an annual expenditure in this area of 70 professional man-years distributed as follows: 15 toward improving pneumatic agricultural tractor tires; 10 on improving crawler and other tractor devices; 15 on the effect of soil physical properties on plant growth; 15 on the effect of equipment mechanics; 5 on methods of mathematical analysis; and 10 on systems of equipment for conservation farming.

Traction and Transport Devices and Soil Reaction. This project is designed to determine and evaluate the effects of various construction, materials, and operational factors on the performance of tires and tracks when used for traction and for transport. Ten American made and two foreign made rear tractor tires were obtained through the efforts of the ASAE Tractive and Transport Efficiency Committee and tested. These tires differed in construction as follows: (1) regular profile-regular cord angle, (2) regular profile-radial cord angle plus belt (a tread ply of circumferential cords), (3) flatter profile-radial cord angle plus belt, (4) as for (3) but foreign made, (5) as for (2) except built to go on a 3-1/2-inch rim, and (6) as for (3) except built to go on a 3-1/2-inch rim. Each type was available also with the lugs ground off to simulate smooth tires.

The twelve tires were tested to study tread movement under two loads and at three inflation pressures. These tests show that tire design and operational differences produce characteristic differences in tread movement. These differences do not correlate with tractive performance and only partially with wear performance.

The twelve tires were tested in three soils and on concrete to measure the effects of the characteristics listed above on traction. Radial ply construction gives the largest improvement in pull. Radial ply and narrow rim construction improve power factor and other measures about equally and contribute more than flattened tread. Lug stiffness improves performance.

The foreign made tire was superior, especially in efficiency. It incorporates radial ply construction, a belt, flattened tread radius, and relatively stiff lug construction.

A rear tractor tire treated with a selected "parting compound" was tested to determine its effectiveness in shedding mud. The improvement noted was not sufficient to warrant recommending its use.

Effect of Tillage Practices on Plant Growth. Studies of basic factors applicable to the design of subsurface tillage implements were continued in 1960. Rooting of cotton was definitely deeper where the soil was well pulverized to a depth of 18" (by successively deeper passes of a sweep cultivator). The yield of cotton was 1.68 bales per acre on deep tilled (18") Lloyd clay loam as compared to 1.38 bales per acre on conventionally tilled plots (6" deep). There was no difference in the yield of cotton in 1960 between Lloyd clay loam tilled 12" deep with a vertical shaft rotary tiller and tilled 6" deep with conventional equipment.

In 1961 all plots of the 18" vs 6" depth of tillage experiment were treated the same to determine the carry-over effect of the deep tillage treatment. The yields of cotton were 1.67 bales/acre for deep tilled

(18") Lloyd clay loam as compared to 1.53 bales/acre for the check treatment (6"). In a deeper tillage experiment the rooting patterns were strikingly different and the yields statistically different. For the treatment of 36" depth of tillage and 36" fertilizer depth, the average length of taproots was 14.5" and yield 1.86 bales/acre; for 36" depth of tillage and 6" fertilizer depth the average taproot length was 13" and yield 1.71 bales/acre; and for the 6" depth of tillage and 6" fertilizer depth taproot length was 8.3" and yield 1.53 bales/acre.

The effect of cropping system and depth of seedbed preparation on peanut production was continued in 1961 for the third of 5-7 years. Results show that tillage and the amount of litter turned appeared to have little effect on the yield. This is contradictory to results of a similar experiment at another location. Yields following rye were significantly higher than for corn, cotton, or soybeans. Rye stubble was some better than where straw residue was incorporated.

Measurement of Soil Physical Properties. Evaluation of methods to determine tensile strength of soils was continued to include the influence of methods of molding on the ultimate strength and a comparison of simple tension and modulus rupture using Lloyd clay. Soil strength increased linearly with molded bulk density and increased with an increase of moisture content (but not exceeding the upper plastic limit) during molding. Tension and modulus of rupture measurements resulted in the same ultimate tensile strength. Measurements of draft, horsepower, and performance in turning soil were made for two high speed and a general purpose moldboard plows at 5, 7, and 9 inches plowing depth at speeds from 1 to 8 mph. The three plows performed about the same.

Equipment Mechanics. Results of tests made in 1961 to compare spherical, conical, and "Vertedor" disks in the Lakeland sand indicate that at a 35°disk angle the soil exerts a much greater downward force on the conical disk than on either of the other two. The "Vertedor" disk is a disk produced in Argentina which has a center section (approximately one half of the disk diameter) in which the curvature is reversed from that of the conventional disk shape. The "Vertedor" disk required about 20 to 25% more draft than the others. At a 45° disk angle, the regular (spherical) disk had a greater downward soil force than the others, while the "Vertedor" again required about 20% more draft. The action of the soil turned by the "Vertedor" disk indicates that it should do a better job of covering any material on the soil surface.

A comparison was made in sand and clay soils of forces on various moldboard landsides, shares, and colter equipment combinations. There was no big difference in the various landside arrangements. The disk jointer gave over 10% reduction in draft compared with the next closest colter arrangement. This reduced draft was accompanied by a reduction in the vertical force and an increase in side force. The principle of multiple cuts, such as demonstrated in these test by a disk jointer - moldboard

plow, offers possibilities of more efficient tillage.

Soil forces were determined on several commercially available 14-inch moldboard plow bottoms to evaluate their relative performance. Speed had more effect on the magnitude of soil forces than did differences between bottoms. Data show that there were differences in the bottoms; however, since the bottoms were tested in only three soil conditions at one depth, a clear superiority of one bottom over another was not established. In general, draft varied directly with the amount of lateral movement of soil.

Relative performance was determined for a conventional 14-inch moldboard plow, the Rotaspa plow from Holland (spades rotate about a hortizontal axis that is perpendicular to direction of travel), and the Civello plow from Italy (curved blades rotate about a vertical shaft). In Decatur silty clay loam the Rotaspa plow gave a range of clod sizes from 0.7" mean weight diameter (MWD) at a forward speed of 0.25 mph to 3.25" at 1.3 mph. The Civello plow produced a MWD clod size of about 1" at forward speeds from 0.5 to 2.5 mph. The moldboard plow produced a clod size of approximately 2" at speeds from 2 to 6 mph. The efficiency of the Rotaspa and the moldboard plows was about the same when producing clods witha MWD of about 2". The efficiency of the Civello was less than one-half that of the Rotaspa when producing clods with a MWD of approximately 1".

Preliminary attempts to separate draft into the basic components of cutting, soil on metal friction and shear plus acceleration, showed the percentage of total force at 9 mph of cutting, friction, and shear plus acceleration to be 50, 8, and 42 for Lloyd clay; 42, 3, and 55 for Hiwassee sandy loam; and 35, 10, and 55 for Lakeland sand. Using similarity of soil reaction to verticalplane chisels from 3/4-inch to 4-1/2 inches wide in Lakeland sand, Hiwassee sandy loam, and Lloyd clay and formulated Pi terms, the data indicate that, with few exceptions, results of the models could be used to make acceptable predictions of the 4-1/2-inch prototype.

Validity of an equation by Zelenin for predicting resistance forces in cutting soil with plane metal surfaces was determined in three of the bin soils. Due to the exponent of depth decreasing with depth of cut, increasing with clay content, increasing with the angle of inclination of the cutting blade within the surface 8 cm., and the inability of the penetrometer to adequately describe soil strength, it was concluded that Zelenin's equation is not useful for general application.

In a laboratory experiment the influence of electro-osmosis (current flow across metal-soil inter-face) on the coefficient of sliding friction of metal on soil was determined for six bin soils and the coefficient of friction of Teflon plastic on the same soils was determined. Results of electro-osmosis ranged from negative at low moisture contents to a

maximum reduction of mechanical power of approximately 95% in moist Houston clay. Usually there were no reduction in total power requirements. Field tests of plastic covered moldboard plow bottoms showed that both Teflon and Polyethylene coverings did a good job of scouring the very sticky subsoil and covering debris. In 1960 tests, field life of the 0.135-inch thick high density Polyethylene was 15 acres and of the 0.2-inch thick Teflon was 50 acres. Field studies in 1961 confirmed that the volume wear resistance of Teflon is much greater than Polyethylene although laboratory studies indicated little difference.

Tests were made with various contents of spindle oil and ethylene glycol liquid binders in Houston clay to determine if it were feasible to use artificial soils to simulate natural field soils in laboratory tillage studies. Draft and velocity dimensionless parameters proved valid in predicting results of the 3.0 in. chisel from that of the 0.75 in. The correction factor $1/2n^2$ satisfied distortion inherent in the system. Since spindle oil has a low volatility rate and since a big loss in content affects strength properties very little, it is an excellent liquid binder for relative tests over a long period of time. Ethylene glycol imparted plastic properties to the soil and is a satisfactory fluid binder if necessary precautions are taken to keep down evaporation. It offers many possibilities of varying the soil parameters for both similitude and comparative tests.

Methods of Mathematical Analysis. Modifications have been made in the triaxial apparatus so that three dimensional stresses, three dimensional strain, and volume strain can be simultaneously measured and recorded on a volume element of soil. Satisfactory simultaneous measurements of stress and strain provide a means for determining stress-strain relationships for soil. A series of triaxial tests on four different soils was completed to determine the relationship between applied stresses (forces) and resulting volume strains (deformations) using soil screened through a 2 mm sieve and wetted to a uniform moisture content. The measurements at each applied stress state were replicated at least three times in Hiwassee sandy loam, Congaree silt loam, Lloyd and Houston clay soils. Because of the tedious nature of executing triaxial tests, two men required approximately three months to obtain 100 valid tests.

Invariants of the stress state, maximum normal stress, mean normal stress, maximum shearing stress, and octahedral shearing stress of soil, were compared with the resulting bulk density for the various manners of applying the stresses. None of the above invariants correlate with bulk density although the mean normal stress was much better than the others. Further analysis showed that a stress function composed of the mean normal stress plus the mean normal stress multiplied by shearing strain correlates with bulk density. Additional measurements on other soils and at different moisture contents will be required to fully verify

the relationship. To be useful, shearing strain will ultimately have to be related to applied stresses.

Systems of Equipment for Conservation Farming. Studies were continued on the effect of various seedbed preparation methods on initial stands, plant heights, silking dates, and grain yields on different soil types. Five seedbed preparation systems and two levels of fertility were used in these studies. Similar to previous results, soil moisture and climatic conditions seemed to have a greater effect than the seedbed preparation systems. Stand counts made prior to cultivation indicate that conventional, wheel-track, and ridge planting give better stands than mulch tillage or listing. These differences in stand are not always reflected in yields, and for the most part conventional tillage results in the highest yields, with wheel-track and ridge planting resulting in slightly lower yields.

Studies were continued on equipment and methods for preparing seedbeds and controlling weeds on ridge planted corn. (Ridge farming is similar to listing except that the crop is planted on top of the ridges rather than in the furrows, and on sloping land the ridges are laid out on the contour or with a slight grade. This system holds promise for preventing soil and water erosion, for reducing drowning in areas that need drainage, and for lowering labor and power requirements.) Corn planted on ridges tends to silk slightly earlier than with the other systems, and listing usually silks last. There was very little difference among the tillage systems for nitrogen and potassium uptake; however, listing tended to be lowest. Through the use of pre-emergence chemicals on contoured ridges that had been formed several years ago, it was possible to obtain almost complete control of runoff and erosion and to maintain a high level of stands and yields. Forming ridges with the plow (one-third of the land area was plowed) and shaping with disk-hillers results in stands and yields that are approximately the same as those obtained with conventional seedbed preparation. Complete rotations of corn-corn-oats-meadow have been grown on ridges in several fields.

Studies on the use of herbicides to eliminate seedbed preparation were continued. Early spring applications of atrazine, Simazine, and 2,4-D in the form of overall sprays were used on fall plowed, spring plowed, and unplowed cornstalk ground. Secondary tillage treatments of disking, strip tillage for only the corn row with a cultivator sweep, and tillage of an 8" strip for the corn row with a rototiller, were compared with no secondary tillage and with conventional plowing, disking, and harrowing. Results of these tests show that herbicide applications can be successfully substituted for seedbed preparation with tillage tools on fall plowed, spring plowed, and unplowed cornstalk ground. With atrazine and Simazine no mechanical cultivations were needed. However, mechanical cultivations were required when 2,4-D was used and also when no chemicals were used. On spring plowed land, none of the secondary

tillage operations significantly improved yields or stands. Although the stand and yield data were somewhat erratic, the results on fall plowed land indicate that tandem disking just before planting was superior to strip tillage or conventional single disking and harrowing. On unplowed land strip tillage was equal to disking and harrowing, and no tillage resulted in lower stands and yields. Cornstalks clogging the planter on untilled plots caused the poor stands that resulted in yield reductions. These results indicate that corn can successfully be grown in Central Iowa with little or no tillage if weeds are controlled chemically.

Studies were continued on methods and equipment for measuring soil shear to describe the physical environment for seedbeds. Measuring the energy input-to-failure of undisturbed soil sheared in torsion offers possibilities as a technique for describing seedbeds. Undecayed organic matter in the samples caused some difficulty, but results indicated that adequate results could be obtained by increasing the number of samples.

Studies were initiated on the development of a soil surface profile meter. This device will be used to describe the physical changes that occur on the soil surface as a result of tillage tool operations or plant growth. The device has been constructed and will be field tested in 1962.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE PROGRAMS

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PLANTING AND FERTILIZING OPERATIONS AND EQUIPMENT
Agricultural Engineering Research Division, ARS

Problem. The history of the development of planting equipment now in use is characterized primarily by invention of machines which will plant seed in accordance with accepted practices. Introduction of chemical fertilizers was followed by specialized equipment for spreading this material. Early work on placing fertilizer close to the seed (starter fertilizer) was followed by the discovery that a certain position with respect to the seed resulted in the best response to starter fertilizer for particular crops.

However, there has been very little work on, and there is considerable present need for, precise seedbed requirements for various crops in different areas of the country. This seedbed requirement would include depth of cover, size of soil particles or clod surrounding the seed, degree of soil compaction necessary, and soil surface profile over the seed for best emergence. The planting geometry used on many crops is still the plant spacing which was necessary to permit horse cultivation. The exact best planting geometry for many crops is still unknown. The exact best placement for starter fertilizer is also unknown for a number of crops in different areas of the country. There is also a need for development and testing of fertilizer application equipment for unusual crop situations, such as hillside orchards, sugarcane, tree transplants, etc. While efforts in precision planting of crops in the past have not often resulted in discernible yield improvements, there is a renewed interest in precision planting of vegetables to improve uniformity of maturation to facilitate mechanical harvesting. As other needs for hand labor diminish and it becomes less available on farms, there will be an increasing need for completely automatic transplanting equipment which does not yet exist. There is an acute need for new and improved equipment and methods for effective planting of native range grasses in the arid areas of the Southwest which will result in a greater certainty of stand. Equipment is needed which can be used to re-seed relatively rough areas which are overgrown with undesirable species or have recently been cleared. There is also need for improved planting equipment and methods for forage crops in humid areas. Approximately a third of such plantings now result in poor stands and another third result in no stands at all.

USDA PROGRAM

The Department has a continuing long-term program involving engineers, of applied research on planting methods and means of applying fertilizer on various crops. Studies are underway at 30 locations in 14 states (Arizona, Delaware, Georgia, Indiana, Iowa, Louisiana, Maryland, Michigan, Missouri, Nevada, New Jersey, Texas, Washington, and Wisconsin). Sixty three field experiments were conducted in 1961 in cooperation

with the experiment stations of these states, other ARS divisions, and some commercial research units. This research involved studies with 34 crops and 24 special machines were provided to put in seed and fertilizer placement experiments this season - machines either solely or collectively designed and constructed by the Investigation Unit. Five new machines were designed and constructed by the research engineers, and alterations and refinements were made to several special machines used this year.

The Federal scientific effort devoted to research in this area totals 9.5 professional man-years. Of this number 0.2 is devoted to seed bed requirements; 1.1 to fertilizer placement and distribution equipment; 0.2 to seed planting equipment; 0.3 to transplanting equipment; 2.5 to equipment for establishment of forages; 2.1 to cotton planting and fertilizing equipment; 0.4 to vegetable planting equipment; 2.0 to decontamination of agricultural land; and 0.7 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 17.2 professional man-years divided among Regions as follows: North Central Region 4.6; Northeastern 0.6; Southern 10.3; and Western 1.7. By major subheadings for the states the man-years were as follows: seed bed requirements 2.4; fertilizer placement and distribution 4.6; seed planting 1.6; transplanting 2.3; forage and rangeland 0.9; cotton 3.4; and vegetable 0.8.

The current program of research by industry in this area was chiefly by the farm equipment manufacturers and the fertilizer manufacturers, a total of about 70 professional man-years. It is estimated that the research by the farm equipment manufacturers was distributed about as follows: seed bed equipment requirements 5; fertilizer placement and distribution 10; fertilizer corrosion 5; seed planting 25; transplanting equipment 5; and forage and rangeland planting equipment 10. Manufacturer's work in sugar beet planting equipment and cotton planting and fertilizing equipment is included under "seed planting equipment" above. It is estimated that fertilizer manufacturers are expending the equivalent of about 10 professional man-years for research and development in this area.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Fertilizer Placement & Distribution Equipment. Twenty-three field experiments were conducted at 14 locations in 1960. Vegetable and root crop tests were conducted in Arizona, Georgia, Michigan, New Jersey, Pennsylvania and Washington; small grains in Michigan and Texas, and row crops (corn and cotton) in Maryland, Nebraska, Nevada and Texas. The experiments conducted involved the use of 9 special machines designed for this purpose. The yields of winter wheat in Indiana in 1960

gave significant differences where fertilizer was placed in continuous bands 1" below the seed with 900# 5-20-20 fertilizer per acre when compared with the common method (contact w/seed, 31 - placement, 36 bu/A). Differences were also secured on the 600# and 300# rates, although they were not statistically significant.

In 1961, the establishment of field crops and vegetables were put in. Seventeen experiments were handled out of the Beltsville Station, three by the Southeastern Station and eight by the Southwestern Station. Some of the notable results in 1961 included response on: fertilizer placement on winter wheat, fertilizer application at time of planting tree seedlings, and application of high phosphate fertilizer at time of planting tomato seed. In cooperation with Michigan State University, a field experiment with the Investigation's special drill for research on winter wheat showed an increase over conventional drilling in 7" rows in contact with fertilizer of 15% greater yield (37.5 to 43.3 bu/A) by placing the fertilizer in a continuous band to the side and below the seed row (about 1" X 1"), or a 19+% greater yield (37.5 to 44.8 bu/A) by drilling in 4" rows (instead of 7" rows); or the combination of the above two practices gave a crop yield increase of 37% (37.5 to 51.3 bu/A - fertilizer contact with seed in 7" drill rows vs. fertilizer side placed to 4" drill rows).

Fertilizer placement studies were made on corn in 1960 and 1961. In conventional planting, the initial fertilizer containing 1/3 of the nitrogen is applied at planting time 2" to one side and 2" below the seed, and the remaining 2/3 of the nitrogen applied as a side dressing 8" to the side of the row, 2 to 3" deep. Results of two years' studies have shown that higher yields can be obtained by using either of the following treatments: (1) same initial placement as conventional but with the side dressing placed 8" deep in the middle, or (2) all fertilizer applied at the time of planting placed 2" to the side and 2" below the seed.

Transplanting and Fertilizing Equipment. In cooperative tree planting on Maryland State Park lands with the W. R. Grace and Company (Fertilizer Research Division) the application of a specially designed fertilizer expressly for silviculture (magnesium ammonium phosphate, 8-40-0) at time of transplanting gave better wood growth in the first season on many species put out in replicated plots - Austrian pine, 15%; loblolly pine, 40%; tulip poplar, 67%; and black locust, 307%. In the past, adding fertilizer at time of transplanting of tree seedling has been considered an adverse practice in that the competitive plants usually first benefit from the added plant food. However, with the new fertilizer and techniques being developed, it appears the early stand and growth can be greatly increased.

Equipment for Establishment of Forages. In 1960 ten experiments on the establishment of pastures and haylands were conducted from the Beltsville station, twelve from the southeastern station, and ten from the southwestern station. As reported previously, many experiments showed earlier growth and more vigorous stands of forages with precision planting of seeds and placement of fertilizer at time of planting, in comparison with the common method of broadcasting seed and fertilizer. These differences were shown under conditions where the growing environment was poor - inadequate moisture and/or low fertility. In the Southeast, insects (army worms), weeds and extreme dry weather made several experiments unproductive. Precision planting and placement of fertilizer gave superior stands with birdsfoot trefoil in the Columbia, Tennessee area. Contact of phosphate fertilizer with this same variety in Georgia gave adverse results on establishment.

At Beltsville, a series of forage crop experiments were conducted on the growing of corn for green feed or silage. This is drilling corn with a grain drill at a rate of 3 1/2 bushels to the acre (some 300,000 plants per acre). No cultivation is required. This solid corn planting is harvested 6 to 8 weeks later when the corn is some 4' or 5' in height. Large tonnages were harvested (28T/A) but with a relatively high moisture content (85 to 90%). Nevertheless, two crops of this nature may be easily produced in this latitude which adds to the flexibility of a farm forage plan. With good practices, one should average almost double the dry matter normally produced by cultivated corn for silage. The principal disadvantages were greater seed cost, higher moisture content material to handle, and slightly less protein content of the roughage. On this heavy producing, short period growing crop, some small advantage was obtained from precision planting and placement practices, but with this first exploratory type experiment, it does not appear this type of culture will require new types of planting and fertilizing equipment.

In the Southwest, establishment of some ten varieties of forage had relatively poor results. Lack of adequate soil moisture in the seed zone seems to be the predominant establishment problem in the high plains area. Basic work on mulches, synthetic covers and other devices are being studied in the laboratory. At the present time, properly managed plastic films on the soils may effectively establish grasses, but the cost (materials and time) limits these methods to relatively small areas at the present time.

Two experiments on the use of liquid fertilizers were conducted in cooperation with the Georgia Experiment Station. No differences were found on crop production on millet and rye in comparison of solid, liquid and suspension type of fertilizers (second year). Response was significant on side placed fertilizer on millet in comparison with fertilizer in contact with the seed.

Nineteen experiments were conducted from the Beltsville Station in 1961, six from the Southeastern Station and four from the Southwestern Station. Outstanding finds this season include the use of nitrogen in the precision placement of fertilizer in the establishment of alfalfa. Cooperative studies in Piedmont soils in the Southeast showed significant increase in first yields of forage production with nitrogen in mixed fertilizer at time of establishment in comparison with the same treatment having no nitrogen in the banded fertilizer 1" below the seed. Also, after two seasons, in Georgia, forage production was increased over 1-1/4 ton per acre by the fall seeding of rye in bermuda sod in addition to some apparent increase in bermuda grass production.

In the Southwest, the record of four seasons on surface pitting and staggered listing on rangeland (for moisture conservation) shows the annual production of grass forage is being increased from 13% to 18% in comparison to the unaltered rangeland. Considerable amounts of weeds were present in the disturbed soil areas the first and some of the second season, but after this initial set-back in desirable forage plants, good range grass stands were established in the raw areas where the basins were formed. Blank listing in 20-foot strips on contour showed superior forage production to range pitters, except during the 1961 season.

Considerable progress was made in methods of establishing birdsfoot trefoil in grasslands in cooperative experiments with the Maryland Experiment Station. Special equipment to study methods by means of a single row treatment were designed and constructed. A single disc coulter gave excellent stands when used in conjunction with the common grassland drill shovel openers, which place fertilizer some 1 to 2 inches below the drilled seed in the grooved furrow. A specially designed winged opener also showed good performance. The new methods average 6 to 7 times more plants in the furrow than the conventional opener (6 week stand - Oct. 20). By March, all stands were reduced in number of plants, but 15 to 18 times more plants survived with the new methods. The results of this one season of work lead us to believe that birdsfoot trefoil which is ordinarily difficult to grow in grass stands, may be reintroduced in sod by these new methods.

Cotton Planting and Fertilizing Equipment. If crop residues do not decompose during the winter they often interfere with planting and other mechanized production practices. This problem is more common to the drier areas of the Cotton Belt but also occurs in the more humid areas where large cotton stubble and root crowns often fail to completely decompose. Two years ago the use of a special root and stalk disposal machine caused a slight delay in the maturity of the succeeding cotton crop in California probably because the nitrogen was not available during the early growth, but this effect was not significant this year. This machine used without any other primary tillage produced yields comparable to standard practices of seedbed preparation. Vertical mulching which placed three tons of cotton stalk trash per acre in a

subsoil trench two inches wide and 20 inches deep increased early growth and yields significantly over standard plowing but not over subsoiling alone at the same depth. A similar vertical mulching test with gin trash in Mississippi three years ago gave similar results of no response and there were no detectable residual effects on the plots in 1960.

More recently a new term, "precision tillage," coined to describe deep tillage in a position to be precisely under the row of plants, has attracted attention to project studies in California. Precision tillage gave an average yield increase of 37 percent in 1961. Tests indicate that the previous benefits of vertical mulching can be explained by the subsoiling rather than the mulch material.

Under the wet fall conditions during 1961, positive operating height adjustments for trailing-type horizontal-blade stalk cutters were attained by adding extra wheels to the conventional cutter. This allowed the outside wheels of the dual wheel arrangement to ride the shoulders of adjacent rows rather than follow the ruts left by cotton harvesters. By equipping the towing tractor with steel skeleton wheels, travel through rough, muddy fields was accomplished without the usual slippage of rubber-tired units.

Land grading is proving a greater asset to mechanized cotton production in the Mid-South Delta area than to the irrigated areas for which it was originally initiated. A 35-acre research field, graded for mechanization studies in 1960 permitted more efficient irrigation, more uniform stands, more timely operations, and more reliable plot results. Two 2 1/2 cubic yard scrapers were operated in tandem with a standard 55 horsepower tractor in correcting the topography of a typical Delta field to a side-slope of 0.05 and row-slope of 0.15 foot per hundred feet. The time per round was increased by less than 20 percent, by using the two scrapers behind a single power unit.

The Stoneville bed blade was as effective as conventional types of pulverizers in preparing seedbeds for planting in sandy loam soils. Best results were obtained by mounting the Stoneville underground applicator blade on a front-mounted cultivator frame immediately ahead of a V-shaped leveling blade. This arrangement provided a smooth, thoroughly pulverized seedbed for simultaneous planting with a rear-mounted planter. Preliminary test equipment was developed for planting directly behind the primary tillage operation. Equally satisfactory stands were obtained planting directly behind moldboard plowing, chiseling, rotary tilling, and middle-breaking on sandy loam soil. No surface refinement was provided; however, the early weed problem was minimized by the previous grading operations.

In another minimum tillage test in Mississippi, moldboard plowing followed by regular sweep cultivation gave highest yields of cotton, as compared with rototilling, chiseling, subsurface cultivating, and

middle-breaking in a Bosket fine sandy loam soil. The addition of chiseling four to six inches deep in the middles at time of each cultivation reduced yield in all primary tillage treatments. Stand was not affected by method of tillage in the 1960 trials.

An irradiation treatment on cottonseed of 150 milliamps, 60 cycles, 2 millimeters of mercury for one minute improved emergence of acid-delinted and gin-run seed, but had little effect on machine-delinted seed in Mississippi. Again, as in 1958 and 1959, there was a significant difference in rate of emergence among types of delinting for both treated and untreated seed.

"Hopper-box" seed treatment with a fungicide has become a rather common practice in some areas of the Cotton Belt. The addition of the fungicide to the seed in the planter hopper reduces the metering rates of the planter slightly. Laboratory tests were run in California to establish calibration values for this practice.

In a soil temperature, planting study, at two locations in Alabama there was no correlation of minimum soil temperature and cotton stand. Soil temperature guides developed in Texas do not seem to be applicable to Alabama climatic conditions.

The plateau, shallow furrow, deep furrow, and flat row profiles were again compared on sandy soils in the High Plains area of Texas. Plant emergence counts indicated slightly more rapid emergence in the shallower profiles at 10 days after planting. These results occurred with no precipitation and drying winds. There was no difference in final yields. This phase of the planting work in Texas will be terminated. A manuscript is in the process of publication.

Among seed press wheel weights from 0 to 100 pounds, the 17 and 35 pound weights per wheel gave best emergence, agreeing in general with last year's results at Lubbock, Texas.

At Lubbock the emergence obtained for each of several plastic mulch treatments was higher at the one percent level for 17 days after planting except for the first and 17 day. The mean soil temperature ranged two to three degrees higher under clear plastic than under black plastic and uncovered rows. Increased emergence and final yields were obtained by using either plastic cover during germination and emergence. The increased emergence was attributed to a measured trend of decreased physical impedance and increased air permeability and moisture in the seed zone.

A small disc opener was used to apply fertilizer in one trench of the plateau planter slightly below seed level at Lubbock. A rate of 40 lbs. N per acre applied in this manner was as good as higher rates applied in the same manner or later as a side dressing. In another test,

yield results showed that close placement of fertilizer for early use of plants is most important in this area.

Vegetable Planting and Fertilizing Equipment. Tomato seeds were planted in Georgia in 1959, 1960, and 1961, and given varied applications of fertilizer at the time of planting, (radioactive phosphate fertilizer was used the first two years, but that used in 1961 was not radioactive). The Georgia plants were transplanted in New Jersey and given uniform treatment until the maturity of the crop.

Two out of three years showed greater production of tomatoes when heavy phosphate fertilizer was placed below the seed. In 1959, 10 lbs. of P_2O_5 per acre gave a yield of 18 tons of tomatoes per acre compared to 130 lbs. of P_2O_5 which gave a yield of 25 tons of tomatoes; or a yield increase of 7 tons per acre for the heavier application. In 1960, 10 lbs. of P_2O_5 per acre gave a yield of 24 tons of tomatoes per acre compared to 70 lbs. of P_2O_5 which gave a yield of 29 tons; or a yield increase of 5 tons per acre for the heavier application. In 1961, all plots yielded around 31 tons per acre. Evidently the excellent growing conditions for maturing the crop in New Jersey overcame the effects of varying the initial phosphate applications to the seeds in Georgia in March.

Decontamination of Agricultural Land. A study is underway to determine how to remove radioactive fallout from agricultural lands in case of an emergency. Bare soil was treated with simulated fallout (small glass beads 18-40 micron diameter) and subsequently decontamination was attempted with a bulldozer, a road grader, a small and a large pan fill-type scraper and a laboratory designed vacuum sweeper. The large scraper was most effective in removing the fallout as it removed 99.8% of the activity. However, it also removed the topsoil to a depth of seven inches The road grader removed 88% of the activity. The vacuum sweeper removed from 4 to 40%. Although performance of the first design tested was erratic, the maneuverability as well as the comparatively low amount of radioactive material to be disposed of make future developments of vacuum equipment attractive.

In 1961 tests were begun to test means of decontaminating pasture and hayland. Since rainfall affects the amount left on forage crops, tests were conducted with and without the crops exposed to a simulated rain applied with sprinklers. The first inch of simulated rain washed off about 10% of the fallout. Removing the vegetation using a flail forage harvester emptying into a canvas enclosed wagon resulted in removal of about 40% of the fallout. Removing the vegetation by means of a direct cut forage harvester resulted in only about 15% decontamination. While the flail removed more fallout it also scattered more around while it was operating, which was objectionable. A motorized vacuum street sweeper picked up about 35% of the fallout but was difficult to operate over rough land. A road grader removed as much fallout when operating on

standing hay crop as when operating on mowed hayland. A dense crop of soybeans was grown and removed after pasture land was partially decontaminated, in order to investigate the possibility of removing remaining contamination with the heavy vegetation. The effectiveness of decontamination by removing the crops depended on the thickness of the foliage, the amount of rain which washed the vegetation and the type of harvest machinery used.

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FOREST SOIL AND WATER RESEARCH
Watershed Management and Recreation Research Division, FS

Problem. All of the major rivers of the United States have headwaters in forests, associated range lands or alpine regions. To derive the greatest benefits and protection from these headwater areas improved knowledge of the management of watersheds and streams is needed. More than half the waterflow of the country originates in such areas. Whether this waterflow is beneficial or harmful, is well-regulated, sustained flow of good quality or erratic and silt-laden will be contingent to a major degree upon how the headwater lands are managed. Generally accepted estimates of water use indicate a doubling in demand by 1980. The most logical place to look for additional supplies or improved timing of such supplies of the quality needed is in the headwaters. At the same time there are constantly increasing pressures to use these same lands for a variety of products and services in addition to their watershed function. Surveys of soils, which have been in progress on agricultural lands for many years, need to be tried on and adapted to mountainous forest lands. Soil surveys plus additional research are needed to determine how best to adjust these several uses to give the necessary protection and development to soil and water resources.

USDA PROGRAM

This work includes basic and applied research into the relationships of soil, climate, vegetation, and water and the development of methods and techniques to: (1) rehabilitate forest and related rangeland watersheds that constitute sources of damaging flood runoff and sediment; (2) give adequate protection to soil and water resources while forest and related rangelands are being used for timber production, grazing of domestic livestock and big game, wildlife habitat, and forest recreation; (3) increase water yields or improve the timing of such yields under a variety of climatic, soil, geologic, vegetative and topographic conditions; (4) aid forest soil development and improvement; and (5) study the usefulness of soil surveys in the management of mountainous watershed lands. This research is cooperative with ten Federal agencies, twenty-one State, five municipal and sixteen private organizations.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS

Most of the 2.3 professional man-years of research reported in fiscal year 1962 was conducted in the West, with five states working on the problems. Minnesota, Missouri, and Pennsylvania are also conducting studies to learn the best management methods, the most desirable species, and the ecology of watershed plant associations. The problem will constantly grow more acute, and other states are making pilot studies to provide guides for full-scale watershed research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Hydrologic and Erosional Processes

This research consists of a group of basic studies designed to increase understanding of climate, characteristics and hydrology of soils, the functioning of plants in relation to soils and water, and the factors involved in soil erosion and soil stabilization in the numerous forest and related watershed complexes.

1. Snow characteristics and behavior. In seeking methods of increasing snow deposition and prolonging snow melt, snow packs in uncut lodgepole pine areas, 5-, 10-, 20-acres clearcut blocks on north, south, east and west aspects, sampled from March 31 to May 22, 1961, averaged 2.5 inches greater in the clearcut areas than in the uncut. There was no significant relationship between the different sized clearcut blocks. Snow disappearance from the clearcut blocks preceded disappearance from the uncut areas by 10 to 14 days. The greatest response to clear cutting in blocks was on the eastern aspect where the clearcut blocks accumulated 3.2 inches more water equivalent than the uncut areas. In a somewhat similar study in New Hampshire, maximum snow water content amounted to 7.0 inches in a hardwood stand, 5.5 and 5.7 inches in red and white pine plantations, and 6.8 inches in an open field. Melt rates in inches per degree-day over 32° F., after accumulation on March 29, 0.10 inch in the hardwoods, 0.04 and 0.05 inches in the red and white pine stands and 0.11 inch in the open field. This indicates that the snow cover remained twice as long under the pine as in the open.

2. Infiltration. Infiltration expresses the capacity of soils to take up water, and on rangelands being heavily grazed and on forest lands being logged or otherwise used by heavy equipment, this is a serious problem. A study conducted in central Utah on high altitude summer ranges indicates the bulk density of the surface inch of soil, live plant cover density, moisture content of the soil at 1-2 inch depth, air-dried weight of litter and the percentage of clay in the surface inch of soil are all highly correlated with 30-minute infiltration rates, with rainfall applied at 5 inches per hour. Further analysis shows that 49 percent of the variation in sediment eroded is accounted for by the product of percent bare soil and total plot runoff. Slope accounts for an additional 6 percent.

Frozen soils also affect infiltration and when rain falls or snow melts rapidly on such soils, serious flooding often results. In New Hampshire, concrete frost was found to be more prevalent under white and red pine plantations than under a northern hardwood stand. During the spring snow-melt period, frost had a maximum of 42 percent occurrence in the pines as compared to 20 percent in the hardwoods. However, it was observed that snow accumulation was greater under hardwoods and once the

snowpack reached a depth of 18 or more inches, frost penetration was restricted and snow temperatures remained at 31.5° F. At shallow snow depths of 6 and 12 inches, snow temperatures fell well below freezing.

3. Soil moisture storage. The amount of moisture stored in soils and the capacity of soils to store moisture are important in flood prevention, timing of water yield and streamflow, and the growth and production of trees and forage. Much of the research effort at the Coweeta Hydrologic Laboratory is designed to study the water movement through soils to provide guides for later evaluation of watershed treatments. On one gaged 7-acre watershed, a high correlation was found between soil moisture changes and daily streamflow rates. No consistent relationship was found between soil moisture and position on the slope in the surface 4 feet of soil; however, moisture content below the 4-foot depth did increase from ridge to cove. Differences in texture (silt and clay content) tended to mask the effect of slope position in the surface 4 feet of soil.

In a north Mississippi study, thinning 19-year-old shortleaf pine stands to 80 sq. ft. of basal area per acre reduced soil moisture loss during the first and second growing seasons after treatment, and increased the available soil moisture during droughts. Little change in diameter growth was apparent during the first summer after thinning. But during the second summer, pines on deep silt loam increased markedly, and those on clay loam and clay subsoils responded to a lesser degree. Prior to thinning most diameter growth occurred early in the growing season. After thinning, growth was accelerated throughout the growing season but growth was greatest during periods of plentiful soil moisture.

4. Evapotranspiration losses. Water losses from the soil due to evaporation and transpiration are of major significance in the water cycle and offer the best opportunities for water conservation and control. In agriculture, reductions in water loss have been reported by the application of hexadecanol to the soil under a stand of corn. Similarly, a granular form of this mono-molecular evaporation retardant was applied to calibrated high Sierra (California) forest sites in the summer of 1961, at three rates, 35, 130, and 680 pounds per acre. From red fir and natural brush sites, the indicated reduction in water losses ranged from 0.2 to 0.3 inch at four of five sites. At the fifth site, an increase in water loss of 0.4 inch was indicated. At sites where vegetation had been removed by dozing or in which bare ground occurred, reductions in evaporation at the treated sites were from 0.3 to 1.1 inches.

In a study of the processes of water use by plants, the internal water balance of several hardwoods was measured throughout the summer of 1961 at the Coweeta Hydrologic Laboratory in North Carolina. Leaves from trees growing both inside and outside plastic covered plots were sampled and soil and atmospheric stresses were related to variations in leaf-water

deficit. Definite response of leaf-water deficit to soil moisture stress between 0.3 and 2.0 atmospheres was produced within the plots. Leaf-water deficit was shown to depend jointly on soil and atmospheric moisture stress, with flowering dogwood (Cornus florida) being particularly responsive to both factors.

At the Coweeta Hydrologic Laboratory, soil moisture measurements in forested and cleared plots covered with plastic mulch, allowed separation of seasonal transpiration (ave. 14.83 inches) from drainage (ave. 3.26 inches). At the low moisture tension of 1.8 atmospheres soil texture had little relation to transpiration loss but did influence drainage. Drainage amounted to 2.45 inches in fine textured soils and 4.20 inches in sandy soils. Trees drew water from the entire 20-ft. depth of soil sampled, drawing in greatest quantity, earliest and most rapidly where roots were concentrated near the soil surface.

A Missouri soil drying study illustrated the effectiveness of litter in reducing evaporation. Total removal of hardwood trees and their accumulated litter reduced the evapotranspirational soil drying rate by one-third. Where the trees were removed but the litter left intact, the drying rate was reduced by two-thirds. Where the litter was removed and the trees left on the plot, drying rates were increased by 5 to 10 percent.

5. Percolation. Rainfall may infiltrate the surface layers of soil but unless it percolates to deeper depths, it soon shows up as streamflow and can become a major factor in the occurrence of floods. In a study of subsurface stormflow on a forested watershed in central Ohio, 50 to 90 percent of the artificially applied water falling on the surface flowed out from the subsurface layers within four to six hours. Rates and quantities of flow from individual depths and from the entire profile varied with storm intensity, duration, and antecedent moisture tension within the soil. Subsurface flow was most uniform from the 24 to 36 inch zone, ranging from 0.22 to 0.30 inches per hour, regardless of intensity or duration of the simulated storm. Flow was only slightly less uniform from the somewhat more permeable 16 to 24 inch zone but from the highly permeable upper 16 inches, flow was erratic varying with storm depth, intensity and antecedent hydraulic head. Since soil moisture tension was zero at the 16 inch depth, flow from depths lower than this was probably through a saturated medium. Where soil moisture tension was relatively high before and during runs, the greatest quantities of flow were recorded from the deeper zones, and little or no flow occurred from the intermediate depths. This indicates that the lowest zone overlying water-impeding strata must be wetted before flow will occur in the upper zones. Continuing work will relate sub-surface flow to physical soil properties and vegetative soil cover to provide a basis for possible manipulations of vegetation to control stormflow.

6. Soil detachment. Before soil erosion can be controlled, it is necessary to determine and study the factors contributing to its occurrence. In a California study, soils from three parent materials (sandstone, basalt, and grano-diorite) and two cover conditions (grass and forest) were tested to determine the effect of vegetation and parent material upon six soil properties (texture, bulk density, organic matter, total porosity, PH, and mean aggregate size). Soil properties were not significantly influenced by these two vegetation types but parent materials were found to have significant influence on most soil properties. Over 40 percent of the variation in mean water stable size was explained by variation in percent organic matter, porosity, PH and bulk density.

In the Wasatch Mountains of Utah, a 0.1 acre plot of soil, kept clean of all vegetative cover for 12 years, demonstrates the effects of denudation upon runoff and erosion. Thirty-five erosion-producing storms increased bulk density of the surface soil from 0.57 to 1.48 grams per cubic centimeter; porosity was reduced by 35 percent; and surface stoniness increased to almost 20 percent by volume. On the uphill two-thirds of the plot, a relative increase in the sand component, a decrease in silt and a small change in clay occurred. Variations in proportionate removal of soil separates by storms are dependent upon storm amount, intensity and duration. A reduction in residual soil organic matter has occurred.

In a study of soil detachment in Nevada, some of the relationships of overland flow and exposed rock to erosion have been emphasized. Overland flow erodes and transports the detached soil while the presence of exposed rock accelerates the process by creating devious channels which tend to concentrate surface flows. The greater the ground area occupied by exposed rock (up to 23 percent) the more confined are the surface flows and the greater are soil losses. Snow cover, soil frost, and contour furrows reduce soil movement. As long as snow cover persists, it absorbs rain drop impact and reduces erosion in a manner similar to dense vegetation. Soil frost, before it melts, shows a strong anti-erosive influence by binding soil particles and increasing their resistance to this dislodgement. Shallow contour furrows trap soil displaced between furrows by holding back more overland flow.

7. Suspended sediment and deposition. Following destruction of the vegetative cover on the San Dimas (California) Experimental Forest by wildfire, erosion has increased drastically. Average suspended sediment concentration during the four major storms of the 1962 season ranged from 31,000 to 159,000 p.p.m., the concentration depending primarily on rainfall intensity. Streambed profile measurements of two canyons draining 7 to 9 hundred acre watersheds indicate an average aggradation of about 5 feet deposited on a uniform grade of 9 percent through the main channel. Stream gaging Stations in these streams have been buried under debris.

In West Virginia, erosion from a watershed clearcut of its forest cover, with poorly located and constructed skidroads, resulted in continuously high stream turbidities (up to 56,000 p.p.m.), a level considered to be detrimental to the growth of young trout. Light and moderate logging did not produce erosion in quantities harmful to trout. In Michigan, where stream erosion and stream stabilization are being studied on trout streams, measurement of soil loss from eroding stream banks showed an average loss of 12 inches from sand banks but only 1 inch from clay banks. This would indicate that different soils create different problems and require different forms of management for their stabilization.

8. Instrumentation. A part of the job of research is to develop instrumentation where none now exists. In Oregon, an instrument has been developed for measuring water movement through soils, which consists of a displacement flow meter and two porous plates. In operation, there is a continuous water column from the top plate surface through the meter to the lower plate surface. A small quantity of the water entering the upper plate moves through the meter to the lower plate and returns to the soil. Readings from the meter indicate rate of water flow through wet soil. An electrical circuit has been developed for an automatic drop-counter type flow meter.

A laboratory test of a precise electric thermometer for measurement of soil temperature has been completed for use in Oregon, and field trials have shown that bare surface soils are 10° to 12° F. warmer on an average autumn day and 14° to 15° colder at night than corresponding sites under forest litter and canopy. A cover of perennial grass reduces diurnal variation but gives less protection against temperature changes than a forest cover.

To record incoming radiation from the sun, a high output, 180 degree radiometer has been constructed and the potentiometric indicator modified for digital recording with an Eppley standard radiometer. The integration system offers many advantages for remote recording and will permit readings and print-out at one minute intervals with provision for accumulation of readings for daily, or longer, sample periods.

Because undisturbed soil samples are difficult to obtain, a portable hydraulic sampler has been devised in Mississippi. Steady pressures up to 5,000 pounds per square inch make it possible to sample such diverse materials as loose sands, heavy clays, and cemented parent material without the compression or shattering common with samplers driven into the soil by hammer. The sampler consists of a modified 2-ton bumper jack arranged to react against a steel beam held in place by anchors. Interchangeable sampling heads are provided - one tapered for use in soils where equipment is difficult to extract, the other for dry or compacted materials.

In Arkansas a gage has been developed to measure losses or accumulation of soil at a given place. A 25.5 inch bar with attached spirit level, is positioned over fixed reference stakes and stabilized by pins adjusted with screw clamps. Distance from the reference bar to the ground surface is read through 10 holes on 1.33 inch centers by use of a moveable graduated stainless steel rod. A set of 10 readings to 0.01 inch tolerance can be made to two men in 3-5 minutes.

9. Watershed condition and erosion hazard criteria. In the unglaciated area of southeastern Wisconsin, gully erosion in certain forested areas is common, but a survey of 40 completely forested drainages was made and in none of these was gully or channel erosion found. This indicates that concentrations of water from ridgetop farms passing through forested slopes at high velocities have been the cause of the gullies and indicate that gully erosion is not a feature of the natural landscape.

B. Prevention of Watershed Damage

There are many thousand of acres of forest and related lands that are still in good watershed condition. Increasing demand for use of these lands for timber harvesting, grazing, etc., requires that special attention be given to maintaining the present desirable condition of stable soils and controlled streamflow. For the most part this group of studies involves modifications of currently accepted land use practices to give special attention to the prevention of watershed damage.

1. Modified silvicultural and logging practices. On the Andrews Experimental Forest in Oregon, it is planned to separate the hydrologic effects of road construction from those due to logging and harvesting of the Douglas-fir timber. In one watershed, roads constructed in advance of logging caused clearing of 8 percent of the watershed area, but in three years since clearing there has been no influence on peak flows in the stream draining the watershed. However, low flows increased 19.3, 12.4, and 12.8 percent in 1959, 1960, and 1961, respectively. Stream measurements taken in a similar study in Idaho prior to logging and road layout showed geologic erosion of the granitic soils of three drainages, as indicated by sediment movement in the streams, to be 8.0, 9.0, and 13.1 tons per square mile. The higher amount shown for the third watershed reveals the effect of land slumping and channel erosion from a previously stable area, originating from high flows during a rain-on-snow flood event. Somewhat in contrast to this, it was found that during normal flow of streams draining undisturbed, old growth, Douglas-fir watersheds in Oregon, there was essentially no suspended sediment. Suspended sediment under these conditions is moved primarily during the rising stage of streamflow, at which time the concentration may reach 100 p.p.m., still an extremely low level of suspended material.

2. Road development guides. A study in the high mountains of Idaho was designed to provide a basis for planning the best spacing of logging road drainage structures to adequately control overland flow on road surfaces. Analyses show that six factors account for 81.6 percent of the variance in overland flow. The most important (33 percent) is a soil factor involving the ratio of soil particles greater than 2mm. in diameter to water stable aggregates greater than 2mm. diameter. Almost equally important is the gradiant of the road surface, accounting for 31.6 percent of the variance. Other factors of importance are the direction of slope, ground cover on the cut slope, and steepness of the terrain upon which the road is located.

Other analyses from data taken on this area relate watershed and road characteristics to the distance sediment moves downslope from the shoulders of logging roads. Nine factors account for 95.4 percent of the variation in sediment movement distance, 45 percent of this is accounted for by distance from the shoulder to the first obstruction to waterflow. Again a soils factor, the ratio of water stable aggregates to soil particles in the silt and clay size classes is important, accounting for 26.2 percent of the variation. Other important factors are cross-drain interval, steepness of the upper slope, and some stability factors related to soil texture and soil compaction.

3. Operating forest pilot watersheds. In West Virginia, after a commercial clearcut of the timber stand, increases in storm discharge occurred in the growing season. Magnitude of the increase was variable, depending largely on antecedent conditions, and ranged up to about one-half area-inch in any one storm period. Logging disturbance to the forest floor was slight over most of the area so that the increase in stormflow appears to have been caused by a greater storage of soil moisture due to reduction in evapotranspiration, rather than to an increase in surface runoff. The timber harvests were made in 1957 and 1958 and their effects on streamflow are now rapidly diminishing. On the commercial clearcut watershed, increases in growing season discharge were 68 percent in 1959, 41 percent in 1960, but only 5 percent in 1961, of the increase measured immediately following logging.

C. Rehabilitation of Damaged Watersheds

This research is designed to develop techniques and management practices which will restore satisfactory surface flow and streamflow conditions and stabilize and improve soils on forest and range watersheds that have been damaged through past use.

1. Restoring depleted slopes. On eroded, compacted, New Mexico rangelands, soil pitting with a Calkins pitter reduced surface runoff 10 to 26 percent and reduced erosion 16 to 19 percent, measured from 9 separate

rain storms. Soil ripping with an implement called the Jayhawker eliminated practically all of the surface runoff and erosion from 12 rain storms which occurred during the first year after treatment.

Experimental plantings of various species of trees, shrubs, grasses, and forbs for watershed rehabilitation and soil stabilization purposes were made on the eastern slope of the Colorado front range and judged for survival, growth, vigor and freedom from insect, disease, rodent and mechanical damage. Species showing the greatest promise were sand cherry, rose hybrid, silverberry, black mustard, hairy vetch, evergreen sweetclover, and yellow blossom sweetclover. These species will be further evaluated under a variety of growing conditions.

Observations of ground cover density, species composition, herbage production, infiltration, soil stability, soil bulk density, sediment production, and channel erosion in the Pleasant Creek, Utah, watershed were made six years after restoration by reseeding and compared with similar measurements made immediately prior to and 3 years after treatment. Overland flow floods were effectively controlled by the treatment and soil bulk density was lower on all reseeded areas six years after treatment, the greatest decrease occurring on the sites that were most compacted initially. Infiltration capacity has been increased on the poorer sites and vegetative cover improved. During the time the reseeded cover was becoming established, soils stability was less than it had been prior to treatment; however, six years after treatment the soil on most sites has regained its stability and on those sites with the greatest cover improvement the soil is much more stable than before treatment.

Studies on the Gallatin elk range in Montana have shown that ground cover density and soil bulk density were the two most important factors affecting soil movement from study plots subjected to six erosion-producing summer storms. Erosion increased as ground cover density decreased, the increase in erosion being rapidly accelerated where less than 70 percent of the ground surface was covered by plants and litter. As the intensity of rain storm increased, so did erosion. The increase in erosion accelerated rapidly when less than two-thirds of the ground was protected by vegetation or litter cover. Erosion also increased as bulk density of the soil increased, so it was concluded that the management objectives for maintaining or restoring soil stability on the Gallatin elk winter range are a ground cover of at least two-thirds and maximum soil bulk densities of no more than 1.04.

In north Mississippi only three of nine grass and legume species tested showed promise for revegetating and rebuilding badly eroded sites. Weeping lovegrass thrived both on loose sand and on compact silt loam. Switchgrass and rescue grass were much more sensitive to changes in site. Common lespedeza, present only as an occasional plant at the outset,

increased naturally because of the fertilizer added to the grass plantings and by the end of the test occupied from 25 to 90 percent of the plots which failed to produce seeded grass. A common native grass, little bluestem, was able to utilize moisture more efficiently at high tensions than was loblolly pine but the pine was more efficient than was sunflower. The critical season for planted loblolly pine seedlings on eroded areas was found to be the first growing season. In 10 years of test plantings in north Mississippi, 76 percent of all mortality occurred in the first year. This amounted to 19 percent of the total seedlings observed that died in the first season while only 6 percent of the seedlings died during the following two years.

2. Treatment of pilot watersheds. Sediment yield from burned chaparral watersheds near Roosevelt, Arizona, declined through the second post-fire year. Sediment averaged 6,300 tons per square mile compared to 39,000 tons per square mile in the first post-fire year. The sediment measured the second year at the outlets of the watershed appeared to be derived from channel bottom scouring rather than from the watershed slopes.

A depleted, eroding watershed in the Wasatch Mountains of Central Utah was revegetated in 1952, and since establishment of the new cover has not produced a measurable amount of sediment. A companion on untreated watersheds continues to yield sediments during snow melt and more intense summer thunderstorms. No change in ground cover density has occurred during the past five years.

Preliminary evaluation of the watershed emergency treatments applied to the San Dimas Experimental Forest following a wildfire in 1960 shows that planting of barley wattles on the contour are most effective in reducing storm flood peaks and suspended sediment.

D. Water Yield Improvement

This work is designed to ultimately provide methods of management to improve the quality, amount, rate, and timeliness of flow of water yielded from the major types of forest, range and subalpine lands.

1. Conversion of vegetative types. As part of a project to convert sagebrush areas to grass, a study was conducted near Laramie, Wyoming, to determine the rooting habits of high elevation sagebrush plants and how these rooting habits vary by aspect. Root systems of sagebrush plants growing on the ridge, in the bottom, east-facing and west-facing sites were excavated for study. No consistent differences in rooting habits between sites were noted. Root penetration ranged from 4-1/2 to 6 feet and the major concentration occurred near the soil surface. The depth of the surface concentration corresponded to the depth of the "A" soil horizon. Penetration of roots to deeper zones was mainly through

structural cracks or fissures in the soils.

In an experimental watershed in Arizona, 80 acres (1/3 of the watershed) were cleared of timber and planted to grass in 1958. Increase in water yield the first year was not significant but in the second year the water yield increased 2.0 inches over the 4.4 inches estimated as the pretreatment condition flow. In the water year 1960-61, the flow was 1.55 inches, an increase of 0.59 inches over the predicted 0.96 inch flow.

In Colorado, an experimental watershed was cut in 1955 utilizing a pattern of logging which alternately clearcut and left uncut blocks of trees. This removed 40 percent of the timber from a 714 acre, high elevation forest watershed. Each year water yields have averaged about 25 percent above that predicted for the uncut condition and have annually ranged from 2.1 to 4.2 area-inches greater during the five years.

E. Soil Improvement

Research in this area is directed toward finding techniques for speeding up soil development on deteriorated watersheds where top soil horizons have been washed away and infiltration, percolation and water storage capacities are low; and to improve the hydrologic conditions of wetland soils through manipulation and management of water levels.

On eroded Piedmont soils in South Carolina, plots in stands of old field pine were given additions of oak and hickory litter over the naturally occurring pine litter. By the 5th year, the gain in organic matter was significantly greater than on those plots having only pine litter. Gain in organic matter was essentially the same on plots receiving oak litter as on those receiving hickory litter.

Preliminary to studies of soil improvement in the northern forest wetlands areas, detailed data were obtained on one of the peat types in northern Minnesota, in regard to its water-holding capacity and moisture status at different levels above the water table. A satisfactory method of sampling peat soils in a long continuous core has been devised. In another study the important forest humus types of the northern forest region of the Lake States are being examined. Emphasis is being given to the "duff-mull" types and suitable criteria for field identification are being developed.

In the wetlands forest areas of the Southeast Coastal Plain, an analysis of problems has been completed. A survey of drainage practices and successes on test projects made by industry and universities will be made and results compiled and studied. This survey will help guide the next steps of research to be undertaken by the project.

F. Pilot Soil Surveys

A pilot program of soil surveys on the National Forests to determine their value in multiple-resource planning and management on a broad scale and in individual project planning and management on the ground, was initiated in Fixcal Year 1958, under the technical direction of the Division of Watershed Management Research. The pilot program has emphasized three objectives: (1) the survey itself, to identify and map the types of soils occurring on forest lands and to describe their characteristics; (2) the research needed to further describe the characteristics of soils and to interpret those characteristics in terms of the one or more uses to which the soils might be put; and (3) the training and development of men who can perform liaison duties with National Forest resource managers by properly interpreting soil survey information in terms of forest or range or watershed or recreation management or in engineering problems associated with wildland management. The surveys on the National Forests follow the national standards of the cooperative soil survey established in the Department of Agriculture for classification and mapping of soils and is closely coordinated with soil survey activities conducted by the Soil Conservation Service outside the National Forests.

During the pilot area phase, surveys have been made on 28 areas in all administrative regions of the Forest Service, including Alaska. Field work is complete on 16 of these areas and technical reports are in various stages of completion. Technical soil survey reports have been completed and published by the U.S.D.A. for two areas. These reports include: (1) background information on geology, climate, vegetation, land use, etc.; (2) all technical soils information and laboratory analyses for soils and engineering purposes; and (3) a section on the use and management of all the soils included in the survey.

Approximately 40 percent of the soil scientists' time has been given over to specific soil management services and training. In addition, five 2-week schools have been held to give representative field personnel a technical refresher soils course so they might make better use of soils information in their resource management operations. Furthermore, in an effort to reach all resource administrative personnel, a Handbook on Soils has been prepared and distributed to all Forest Service field offices.

Soils surveys on the National Forests have proven to be a useful management tool and a decision has been made to terminate the pilot phase and initiate full scale activities as a part of National Forest resource management. At the same time, technical leadership has been moved from the Division of Watershed Management Research to the Division of Watershed Management, NFRM.

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WEED CONTROL
Crops Research Division, ARS

Problem. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, and irrigation and drainage systems. The losses caused by weeds can be reduced by finding more effective chemical, biological, mechanical, cultural and combination methods of weed control. Improved weed control methods will facilitate farm mechanization, increase production efficiency, and improve the efficiency of the use of human and land resources in agriculture.

USDA PROGRAM

Much of the weed control research in the Department is cooperative with State Experiment Stations, other Federal agencies, industry and certain private groups, and is cross commodity in nature. The total weed control program involves 64.6 professional man-years' effort. Of this total, 13.5 is specifically directed to work with aquatic weeds, phreatophytes, and non-cropland weeds.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Information on the weed research for commodities by State Experiment Stations and industry is not available. For a summary statement covering all research by these agencies on weed control, see pages 240 and 241 in the Crops Research Division report.

A. Aquatic Weeds

1. Physiological and Ecological Studies. At Denver, Colorado, 1,1'-dimethyl-4,4'-dipyridylium cation (paraquat) was the most active compound among 25 tested on three submersed weed species in a standing water situation. In laboratory soil treatment tests, involving 48 chemicals, 2,6-dichlorobenzonitrile was the most active herbicide in preventing growth of waterweeds and warrants further testing in the field.

In controlled environmental studies at Denver, injury to pondweeds from a contact herbicide increased significantly as the culture temperature increased from 60 to 80° F. and as light intensity increased from 25 to 400 foot candles.

At Clarkedale, Arkansas, the rate of release of herbicides from granules in quiescent water was increased as (1) herbicide solubility increased, (2) granule size decreased, (3) water temperature increased. Water characteristics, types of granule and sorptive capacity of granule were also important factors in rate of release of herbicides from granules.

Water stargrass at Clarkedale grew successfully at light intensities as low as 110 foot candles, approximately 1 - 2% of full sunlight, and growth increased as temperature increased from 10 to 30° C.

Dormant lateral buds on alligatorweed stem nodules sprouted and grew stem shoots when excised and placed in moist chambers at Fort Lauderdale. Lateral buds dissected from stem nodes sprouted when floated in water or nutrient solution. The sprouted buds survived transplanting to moist soil and the resulting plants grew normally.

A sago pondweed plant grown from a tuber in an 18 foot diameter tank at Huntley, Montana, in cooperation with the Montana Agricultural Experiment Station produced 6,048 drupes, 804 axillary bulbs and 36,012 tubers in one growing season.

In cooperative tests, growth of field beans at Prosser, Washington, was suppressed when irrigated with 2 acre-inches of water containing 1, 5 or 25 ppm of endothal. 1,1'-ethylene-2,2'-dipyridylium dibromide (diquat) also suppressed bean growth particularly at 25 and 125 ppm. Corn was tolerant to both chemicals at the given levels.

2. Control Studies. Water hyacinth at Fort Lauderdale, Florida, 1/ in cooperative studies with the Florida Agricultural Experiment Station was controlled as well with a single application of 3-amino-1,2,4-triazole--ammonium thiocyanate (amitrole-T) at 1 lb/A as with two or more applications of 2,4-D at 2 or 4 lb/A. Amitrole-T applied with a helicopter at 1 lb/A on a 7.5 acre plot controlled water hyacinth completely for seven months.

Studies at Fort Lauderdale indicated highly effective translocation of amitrole-T in water hyacinth. Amitrole-T moved in either direction from parent plants to attached plants via stolons causing albinism and death, while 2,4-D movement from parent plants to attached plants was not found.

Diquat applied at 3 and 5 ppmw in Florida farm canals gave excellent control of submersed weeds such as southern naiad and coontail. Diquat at 1 ppmw gave complete control of watermeal and duckweed in two different farm ponds.

At Ford Lauderdale silvex was the most promising herbicide found for control of alligatorweed among a group of chloro and fluoro-phenoxy and triazine herbicides. Alligatorweed was 99% controlled nine

1/ Research on aquatic weeds at Fort Lauderdale, Florida, is supported in part by funds transferred from the Corps of Engineers, Department of the Army.

months after treatment with fenac amide at 10 lbs/A in growth pools.

In preliminary field trials fenac applied to canal bottom soils in Wyoming effectively controlled sago pondweed for the entire irrigation season.

Two proprietary emulsifiers, Emcol AD-410 and Toximul H, proved effective in stabilizing dilute emulsions of grade B xylene in irrigation water resulting in excellent control of sago and other pondweeds for 2 to 6 miles in tests in cooperation with the Montana, Washington, and Wyoming Agricultural Experiment Stations. Control of pondweeds varied somewhat for rates of 1 to 2% of emulsifier tests because of wide shallow canals, density of pondweed growth, high velocity of water, and other uncontrollable factors.

Endothal at 3.5 ppmv introduced in a 2-hour period did not control pondweeds in a drain ditch in Washington, but gave effective kill of leafy pondweed in a farm pond in Montana when applied at 5 ppm in an enclosed plot.

B. Phreatophytes

Saltcedar was more sensitive to 2,4-D or silvex when applied in diesel or invert oil than when applied in water in preliminary experiments at Los Lunas, New Mexico.

Saltcedar was effectively killed by two consecutive spring applications of 4 lb/A of silvex in tests at Buckeye, Arizona. Complete control was obtained with a single spring treatment of 10 lb/A.

C. Ditchbank and Other Noncropland Weeds

1. Physiological and Ecological Studies. In studies at Laramie, Wyoming, exposure of atrazine, simazine, diuron, fenuron, and monuron to sunlight for 25 to 60 days significantly reduced toxicity of these herbicides to oats. The decrease in toxicity ranged from 75 to 38% in 60 days for atrazine and monuron respectively.

2. Control Studies. Paraquat at 1.5 plus 2,4-D at 2.5 lb/A was the most effective of 23 chemical treatments in limiting initial growth of miscellaneous ditchbank vegetation at Bozeman, Montana. Combinations of 2,4-D or silvex and dalapon were the most effective in limiting regrowth in this experiment.

Repeated applications of 2,4-D at 40, 60, and 80 lb/A, amitrole at 10 lb/A, and dalapon at 10 lb/A plus a surfactant gave satisfactory control of Carex lanuquinosa in Wyoming.

Amitrole-T plus dalapon was twice as effective on horsetail (Equisetum spp.) as was dalapon alone at Clarkedale, Arkansas.

Reed canarygrass was effectively controlled on ditchbanks in Washington except at the waterline with six treatments in two years with amitrole at 4, 8 and 12 lb/A, amitrole-T at 2,4, and 6 lb/A, dalapon 15, 20, and 25 lb/A. Fall applications of TCA at 130 or 160 lb/A plus seeding desirable grasses the next spring effectively controlled canarygrass on the top and slope of the ditchbank, but encroachment began at or just below the waterline.

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ECONOMICS OF WATER AND LAND USE AND DEVELOPMENT
Farm Economics Research Division, ERS

Problem. The efficiency with which ground and surface water resources are managed in the agricultural sector of the economy has a direct bearing on the Nation's potential for continuing economic growth. The analysis of agricultural water management and development possibilities in such a setting requires basic data on the adequacy of existing water supplies in relation to various economic uses; information about quantities of water likely to be diverted from agricultural uses by industrialization, urbanization and related recreational needs; and knowledge of the extent to which basic water supplies might be effectively increased through such technologic advances as saline water conversion and weather modification, small-scale technologies and practices for more efficient water distribution and application, and watershed management for optimum water yields.

Adequate land resource data and analyses are basic to studies of adjustments in land use made necessary by changing economic conditions, absorption of farmland for nonagricultural purposes, and increasing competition among alternative uses. They are needed to anticipate long-term requirements of land for agriculture, potential capacity to produce, and soil conservation needs.

USDA PROGRAM

Current investigations are concerned both with providing economic facts on water supplies, uses, and management needs as they concern farmers, legislators, or administrators; and with analyzing resulting implications for water management decisions. Intensive studies are concerned with developing economic principles and techniques appropriate to the analysis of agricultural water problems; estimating the water values necessary for determining the feasibility and profitability of new water supply technologies or management practices, small watershed projects or broad river basin programs; and with appraising various legal and organizational arrangements affecting the adoption of improved water use practices and with the implementation plans for multipurpose development of watershed and river basins.

The program of research in the economics of land use and development includes studies of conservation and land development.

Approximately 12.6 Federal professional man-years currently are devoted to the portion of the research program in the economics of water and land use and development covered in this report. Broken down by subareas of investigation, Federal professional personnel commitments

annually are as follows: inventory and appraisal, 2.2; water allocation and management efficiency, 5.6; water development potentials and agricultural requirements, 3.1; and conservation and land development, 1.7.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State research on the economics of water use and development currently totals approximately 7.2 man-years. Of a number of man-years devoted to the economics of land use and development, some are devoted to work relating to that described in this report.

It is estimated that industry and other organizations devote from 40 to 60 professional man-years to the economics of water use and development. The work with land also involves a sizeable effort.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE RESEARCH

A. Inventory and Appraisal of Water Resource Supplies, Uses, and Values

In connection with water use inventories and special appraisals of agricultural water use and supplies, three major reviews have been published. One is a compilation of all sources of available water supply and use data collected by such agencies as the U. S. Geological Survey and the Bureau of the Census. Each major source is described with reference to the type of data given, period and frequency of availability, geographic coverage, and overall completeness. The second review is included in a 5-year periodic inventory of land and water use in the United States (Agricultural Economics Report No. 13) and discussed the general role of water in agriculture, water situations and sources in the eastern and western States as well as trends and uses of irrigated and drained land. The report indicates that irrigation in the United States increased from 8 million acres in 1900 to more than 33 million acres in 1959 (nearly 36 million acres in 1962 if trends are extrapolated). Drainage increased from 7 million acres in 1900 to 102 million acres in 1960. The proportion of irrigation from ground water is increasing steadily, having grown from 17 percent in 1939 to 45 percent in 1959 and reflects full use of available streamflow in many irrigated areas of the West. The third review draws on these and other data in an overall comparison of trends and projections of agricultural and non-agricultural water use provided for the Department's Land and Water Policy Committee and appears in the Committee report "Land and Water Resources: A Policy Guide" issued in May 1962.

Concerning humid-area irrigation trends and potentials, analysis of final Census data shows that irrigation in the 31 eastern States declined by 297 thousand acres between 1954 and 1959, due largely to a 1/2 million-

acre reduction in rice grown in Arkansas, Louisiana, and Mississippi. About 2.3 million acres were irrigated in the East in 1959 compared with 1.5 million acres in 1949. The Department's Conservation Needs Inventory (CNI) indicates that nearly 19 million acres could be eventually irrigated in humid States on the basis of suitable soils and available water. An intensive economic study in the Piedmont and Coastal Plain in North Carolina seeks to estimate the production and water use impacts of supplemental irrigation drawing from soils for a statistical sample of plots surveyed in the CNI, as well as from crop response, water-supply and prototype cost data.

Studies of profitable farm allocations of limited irrigation water in the Upper Colorado Basin are nearing completion at Logan, Utah. A statistical report has been published on farm production practices and inputs in the Strawberry Valley area. Another report undergoing editorial review deals with the profitable use of irrigation water in the Ashley Valley, an area to be supplied supplemental water from the Vernal Unit of the Central Utah Reclamation Project. The study indicates that average returns per acre-foot of water now range from $3 to $5, but that marginal returns associated with supplemental supplies may run to $10 per acre-foot. This work complements a study completed several years ago by Colorado State University under a research contract; the latter study indicated that marginal returns to additional water ranged from about $9 to $18 per acre-foot.

A current analysis of values of water for irrigation and competing uses in the Upper Colorado Basin at Fort Collins, Colorado has utilized multiple regression techniques to first derive values of shares of water stock involved in 800 farm sales occurring since 1954 in Boulder, Larimer, Weld, and Morgan Counties, and then to compute average water values from related information on deliveries per share. Final results are now being analyzed but published findings from an earlier sample of 44 farm sales indicate that marginal returns to additional irrigation water in the North Poudre Irrigation Company service area approximate $30 on a capitalized basis, and about $3 to $6 on an annual basis, depending on respective discount rates of 10 and 5 percent. Additional information on how institutional arrangements for reallocating limited water supplies under appropriative water rights has also been published under this project, and a descriptive study of financial and water-supply characteristics of over 100 irrigation companies in northern Colorado is being processed for publication. A comparable study of values of water for irrigation and competing purposes has just recently been initiated in the Pacific Northwest in cooperation with the Oregon Station.

B. Problems of Water Allocation and Management Efficiencies

Studies of supplemental irrigation in humid areas in Texas are nearing completion with publication of a final report on irrigated cotton production in the Middle Brazos River Valley. Four years of data indicate that irrigation can substantially increase cotton yields in the area but that many of the benefits may be offset by increased harvest expense and grade losses associated with heavy rainfall during harvest seasons. The study suggests an irrigation management program involving a reduced level of water use and fertilizer inputs, as well as a shortened irrigation season to minimize damage from wet fall weather. Net returns from irrigation could thereby be increased considerably over the $51 per-acre annual benefit of cotton irrigation under present management.

Research on supplemental irrigation in Mississippi has involved economic analysis of irrigation channel conveyance losses and comparative costs of sprinkler, gated-pipe and siphon-tube irrigation methods. Seepage losses from channels appear greater for clay soils than for sands and loams, largely because of severe cracking. Minimum seepage from sandy soils was associated with the sealing effects of incorporated silt particles. It was concluded, however, that artificial seepage-control measures would cost more than the value of the water lost under any soil conditions in the area. Evaporation losses from irrigation channels were found to be insignificant. The cost studies of different irrigation methods indicate that fixed costs as well as total annual cost per irrigation were lowest in the case of siphon tubes--annual fixed costs of $3.69 per acre and total annual costs per irrigation of $17.90 per acre. The same cost items ($8.90 and $25.75) were highest for sprinkler irrigation; with gated-pipe representing intermediate cost levels ($7.01 and $24.35).

Economic appraisals of the use of water for irrigation in Missouri have concentrated on the problem of relating probable economic feasibility to the probability of various drought intensities as measured in drought days. Preliminary findings are that drought periods are quite prevalent in southeastern Missouri at least, and that irrigation appears feasible in most years, though probably not requiring equivalent water applications every year.

Studies of the economics of supplemental irrigation in South Carolina are completed, with approved publication of a bulletin on irrigation practices, costs, and returns for the period 1956-59. Average irrigation investments for the following farm types were: Peach, $12,200; tobacco, $6,700; dairy, $5,800; beef, $4,900; and general, $3,800. Rates of average annual irrigation returns on these investments ranged from a low of 1.17 percent on tobacco farms to a high of 14 percent on peach farms,

with the latter followed by dairy farms at 4.27 percent, general farms at 3.26 percent, and beef farms at 2.91 percent.

In the now-completed study of high water table problems on the Newlands Reclamation Project, Nevada, a draft report indicated that significantly reduced crop yields associated with poor drainage could be at least partly restored with better irrigation methods and project-financed water-level control measures.

Research on the economics of watershed management continued at Washington, D. C. and cooperatively with the Iowa Station. A journal article reporting final results of the Spring Valley Creek Watershed research has been cleared for publication and a research bulletin will be prepared in the coming year. Although the study indicated that an optimum allocation of resources in the watershed as a whole is tantamount to an aggregation of optimum farm allocations programmed independently (due to insignificant interfarm problems of flooding and gully erosion), the on-farm benefits of such water management practices as terracing were noted to be significant in terms of complementary erosion reduction benefits. A published analysis of these benefits indicates that a commonly cited 5-ton-per-acre maximum permissible erosion rate in the Midwest would, at least in some cases, be more consistent with maximum farm income if stated as an optimum rate, since erosion near this rate could be accepted along with optimum farming systems.

Washington, D. C. studies on watershed management economics have included (1) preliminary work on analyzing crop yield and hydrologic data from the Blacklands Experimental Watershed near Waco, Texas; and (2) economic review and machine processing of data on potential watershed development gathered in the Department's National Inventory of Soil and Water Conservation Needs. The Department has published 2 inventory reports incorporating the material (Agr. Inf. Bul. 263 on Agricultural Land Resources and Stat. Bul. 317 on Basic Statistics of the Inventory) and detailed interpretive material has been provided for a third general report now in process. Development needs were inventoried for 12,802 tributary watersheds in the 48 contiguous States, Hawaii, Puerto Rico, and the Virgin Islands. Data were aggregated by States, 160 individual river basins, 18 major drainage areas, and, alternatively, 22 water resource regions. Flood plain protection and project measures for erosion control are necessary in 6,378 and 4,662 watersheds respectively. Drainage and irrigation are feasible in 3,950 and 2,635 watersheds, respectively. At least 1,956 projects will involve recreation development and at least 834 will provide rural water supplies for purposes other than irrigation.

A contract study of the characteristics and use of rural flood plains in the United States is nearing completion at the University of Chicago. A final report is now being drafted; additional partial reports covering specific phases of the work have been completed. An unpublished working paper "Appraisal of Flood Plain Data" concerns the form and accuracy of land use and hydrologic data collected by various Federal agencies in their flood control planning activities. A second unpublished working paper "Methods and Problems of Taxonomy" discusses in theoretical terms the validity of classifying flood plains on the basis of central tendencies of observed characteristics. A third report "Types of Agricultural Occupance of Flood Plains in the United States," to be published by the University of Chicago, describes practical methods for classifying significant sets of flood plain characteristics. Another major report "Sampling, Coding, and Storing Flood Plain Data" has been published. This outlines the statistical theory of alternative land use sampling schemes, gives methods for correlating sample observations with secondary data sources, and illustrates a unique field method for punchcard coding and storage of sample data in which schematic land use and soils maps can be reproduced directly from the data cards. Additional reports in draft form include studies of changes in agricultural use of flood plains in the United States and problems in mapping critical combinations of flood plain characteristics as well as a study of the feasibility of preparing a generalized map of flood plains in the United States.

C. Water Development Potentials and Agricultural Requirements

Cooperative research with the Iowa Station on the economics of land forming for water management in the eastern States has involved compilation of costs of such land forming practices as land leveling, shaping and parallel terracing. Also, a preliminary study paper was prepared which traces the history of current interest in land forming in the East and, with respect to various land forming practices, outlines problems of definition, develops a physical-economic classification to guide economic evaluations, and summarizes available information and data regarding trends in their adoption and their associated benefits and costs.

Research on irrigation water conveyance systems in California has identified and analyzed several significant factors affecting the location and design of major conveyance works. The elevation difference between source and delivery areas was found to be a critical element for economic study; this difference greatly affects pumping costs and investment decisions. Other factors isolated through review of project documents and conferences with engineers include uncertainty in amount, location, and timing of future water demands; the influence of administrative pricing on water use efficiency; possibilities for acquiring rights to

additional local supplies as alternatives to water importation; and the increasing importance of water quality considerations as irrigation return flows become a more important source of supply for subsequent uses. Preliminary study reports on various phases of the project have been prepared under the following titles: "Economic Considerations in the Design of Major Water Conveyance Systems," "Economic Design of Canals and Canal Structures;" "Economic Design of Gravity Tunnels for Water Conveyance;" "Economic Design of Pumping Stations in Water Conveyance Systems;" "Economic Design of Lateral Systems for Delivery of Irrigation Water;" and "Economics of Water Quality in the Design of Irrigation Supply Systems."

A joint land and water economics project on testing the adaptability of complex econometric models to interregional land and water planning problems continues in cooperation with the Iowa Station. Progress to date is reported under Area 8: Economics of Land Use and Development.

Limited research continues on the economics of flood control, drainage, land forming and bank stabilization in the Lower Mississippi Valley for the purposes of providing a comprehensive view of water resources development in a region where local, State, and Federal interests have long been active; and for indicating potentials for similar programs in other regions.

Work also continued on developing improved methods for evaluating water resource programs through participation with representatives of the Departments of Agriculture, Army, Interior, and Health, Education, and Welfare in the preparation of a statement on policies, standards, and procedures for the formulation, evaluation, and review of plans for water and related land resource developments. The statement was approved by the President on May 15, 1962, for application by the agencies concerned.

D. Conservation and Land Development

Participation in the National Inventory of Soil and Water Conservation Needs, 1957 to 1962, provided useful data on the land and water resources of the entire country. Aid was given in 1961 and 1962 in the review and analyses of major results of the Conservation Needs Inventory. These analyses have been released in USDA publications which include information on the present acreage of non-Federal land in major uses, the acreage of each use by land capability class, and conservation practices needed to maintain the agricultural land in a productive state.

Results of the Conservation Needs Inventory indicate that in the 50 States there are 638 million acres of non-Federal, nonurban land in capability classes I, II, and III. Land in these capability classes is

physically suited for regular cultivation; about 58 percent of it currently is used as cropland. Approximately 169 million acres of class IV land is suited for occasional cultivation at high cost and with intensive conservation treatment. Of the class IV land, about 49 million acres, or 29 percent, is used for crops. There are about 644 million acres of land in capability classes V, VI, VII, and VIII. In general, land in these classes is not suited for cultivation, although approximately 25 million acres of this land is currently being used for cultivated crops. These data suggest that even though we have a substantial reservoir of land which may be converted to crop uses, some land presently in crops is not being used in accordance with its capability.

Soil and Water Conservation Needs data, particularly those relating to soils, land use, land capabilities, slope and erosion, are being used in current studies of land use, land and water conservation, and economic land classification procedures. Division personnel are working with the Soil Conservation Service in Washington, D. C. and with Statistical Laboratories at Ames, Iowa; Ithaca, New York; and College Station, Texas, where the data are being processed.

Work continued on an evaluation of agricultural drainage and related management of farms in Michigan. Procedures for establishing drainage districts and public drains were reviewed with special emphasis given to problems of financing. Records of 15 inter-county public drains were analyzed. Nearly one-half of Michigan ACP funds are for farm drainage systems, running as high as 95 percent in some countries. Benefits from drainage are significant and from a normative standpoint may not merit the prevailing degree of public assistance.

A bulletin entitled "Michigan Drain Law as it Concerns Landowners" will report on some of the legal problems involving land drainage. This bulletin will be published by the Michigan Cooperative Extension Service. Several other manuscripts dealing with broad aspects of public drainage, conservation, and development programs have been prepared and cover (a) the differential impact that the conservation assistance program may have on various problem areas in agriculture, (b) criteria in selecting analytical procedures for evaluating public developments, (c) the impact of the Federal cost-sharing program in surplus commodity producing areas and low income areas, and (d) the potentialities of public investments for conservation and development as countercyclical fiscal measures.

In the second phase of the land drainage study in Michigan, 45 farmers have been interviewed in the Pickford, Silverwood, and Parkhill-Capec soil series areas to obtain cultural practice, drainage practice, and production data. These data are being correlated to determine the influence of drainage on economic productivity.

A brief study is in progress on the relationship between land use and the capability classification of the land.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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ECONOMICS OF CONSERVATION PRACTICES, FERTILIZER USE, AND CROPPING PRACTICES

Farm Economics Research Division, ERS

Problem. More information is needed for each type of farming region on the production requirements and output obtained from various enterprises with different methods of operation, including especially those practices that aid in soil and water conservation, and opportunities for desirable adjustments, particularly those which conserve soil and water, on farms of different sizes, types, and physical conditions.

USDA PROGRAM

A continuing long-term program of research dealing with research-product relationships on samples of individual farms in representative farming areas is conducted in cooperation with State agricultural experiment stations. The work also involves the collection of pertinent data and the economic analysis of developments in the use and effects of fertilizer and related crop practices.

A total of 6.5 Federal professional man-years is devoted to this area of research-- 3.4 man-years in the economics of conservation practices; and appraisal of fertilizer use and cropping systems, 3.1 man-years.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Some of the State experiment stations are also working in the area. This work as a whole covers the same sub-areas as the USDA program but each State tends to center its efforts on aspects of particular local importance. A sizable proportion of this work is in connection with regional research projects.

Industry also does some research in this area. Most of this can be characterized as "operating research" but some of it is of sufficient scope to be comparable to that of the USDA and State experiment stations.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE RESEARCH

A. Economics of Conservation Practices

A Wisconsin study estimated the relative profitability of each of eight individual soil conservation practices as well as the aggregate profitability of several combinations of practices. Terracing provided the highest net farm income and interplanting the lowest. The difference between the two practices was $3,076. When five practices

with the highest net income were used in combination, net farm income was $370 more than with terracing alone. Thus if a farmer found it more practical to use only one or two practices such as terracing or terracing and interplanting, he would not lose much in comparison with using several practices in combination. A publication entitled, "Relative Profitability and Order of Adoption of Soil Conservation Practices," is now in the process of publication. This line of work was discontinued as of August 1962.

A study of obstacles to soil conservation in western Iowa found that the significant obstacles were (1) operator's need for immediate income, (2) operator's failure to see the need for recommended practices, and (3) field and road layout of the farm. Characteristics which explained a significant amount of soil losses were (1) topography, (2) soil conservation district participation, (3) operator's ability to borrow funds for erosion control practices, (4) days of off-farm work, and (5) recognition of the seriousness of the erosion-control problem by farm operators.

A study of the changes in use of flood plain lands in Wisconsin watershed projects found that by the end of the 1961 crop year, approximately 250 acres of flood plain land had been converted from pasture to cropland or an average of 5.1 acres per farm. The original work plan provided for the conversion of 449 acres. Cash farm income "before" flood control averaged $6,054 per farm, leaving a net cash income per acre of $39. Farms averaged 66 crop acres per farm. The Soil Conservation Service estimated that each acre converted from pasture to cropland was worth $22. This was computed as the difference in net income return per acre between flood plain cropland and pasture. Significantly, net cash income per acre only increased to $41 by the end of the 1961 crop year or "after" flood control. This indicates that land converted on the flood plain, at least to the present date, had very little effect on the farm income. The greatest restraint was found to be the lack of crop acres in total farms averaging 187 acres per farm with 66 acres in cropland. Past research, coupled with the research findings of this study, points to the fact that farmers, where the Fayette soils are dominant, need at least 90 crop acres in order to operate efficiently. The study also revealed that converting acres from pasture to cropland on the flood plain may not always result in increasing total crop acres. It was significant that over the period from "before" to "after" flood control, average crop acres per farm actually dropped from 66 to 65 acres. This would imply that converting acres from pasture to cropland on the flood plain may not always result in more crop acres although such land might be badly needed. The increase may be absorbed by farming less on steeper slopes. It was found, however, that under higher levels of management and provided land resources were adequate, cash farm income could, in the

future, be increased to more than $16,000, with an average net cash income per acre of $88 and a conversion value on the flood plain of as high as $62.

B. Appraisal of Fertilizer Use and Cropping Systems

Aggregate estimates from pilot studies in selected areas and for types of farms of the Georgia Piedmont area and Missouri, under specified assumptions as to the level of technology on farms, provide projections showing a very marked decrease in acreage of land farmed.

One set of projections for a part of the Georgia Piedmont is based on normative solutions for crop-beef farms for different operator income levels. These solutions are related to 1980 projections of numbers of farms by income classes that indicate 35 percent fewer commercial farms, but an increase of 50 percent of those with gross rates of over $10,000. The price assumptions used in the study were those which have been provided for long-time-projections work of the Department. Under these assumptions there would be a reduction from 1959 to 70 percent in the acreage of land in farms and 55 percent in the aggregate capital investment. Aggregate net farm income would be down about 9 percent in this area, but income per farm would be up about 40 percent compared with estimates for 1959. This projection assumes a level of technology currently in use by leading farmers except that fertilizer use would be optimum for limited capital situations.

Marked shifts would occur in the input composition. Aggregate expenditures for fertilizer would increase four-fold. Expenditures for feed and for hired labor for crop-beef farms would be negligible compared with 1959 outlays for all commercial farms in the area. However, outlays for purchases of livestock would be nearly 3 times as great. These illustrative results compare projections for crop-beef farms with the average of all commercial farms as organized and operated in 1959.

The effects of changes in technology on the organization of resources at the micro level can be shown with an example in the Putnam-Lindley area of Missouri. The results of the study show that for medium to large farms the operator's income can be maintained with fewer resources, providing either improved technology or larger quantities of fertilizer, or both are used. With limited capital and by using fertilizer in optimum quantities, improved crop technology would reduce the land base requirements by about 35 percent and total capital investment by nearly 25 percent. By using present technology and increasing fertilizer from the level used in 1959 to the level optimum for limited capital, the farm acreage requirement would be decreased by 40 percent (5 percent more

than the 35 percent indicated above) and the total capital investment requirement would be decreased by 33 percent. Also other input substitution relationships are made apparent.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Appraisal of Fertilizer Use and Cropping Systems

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